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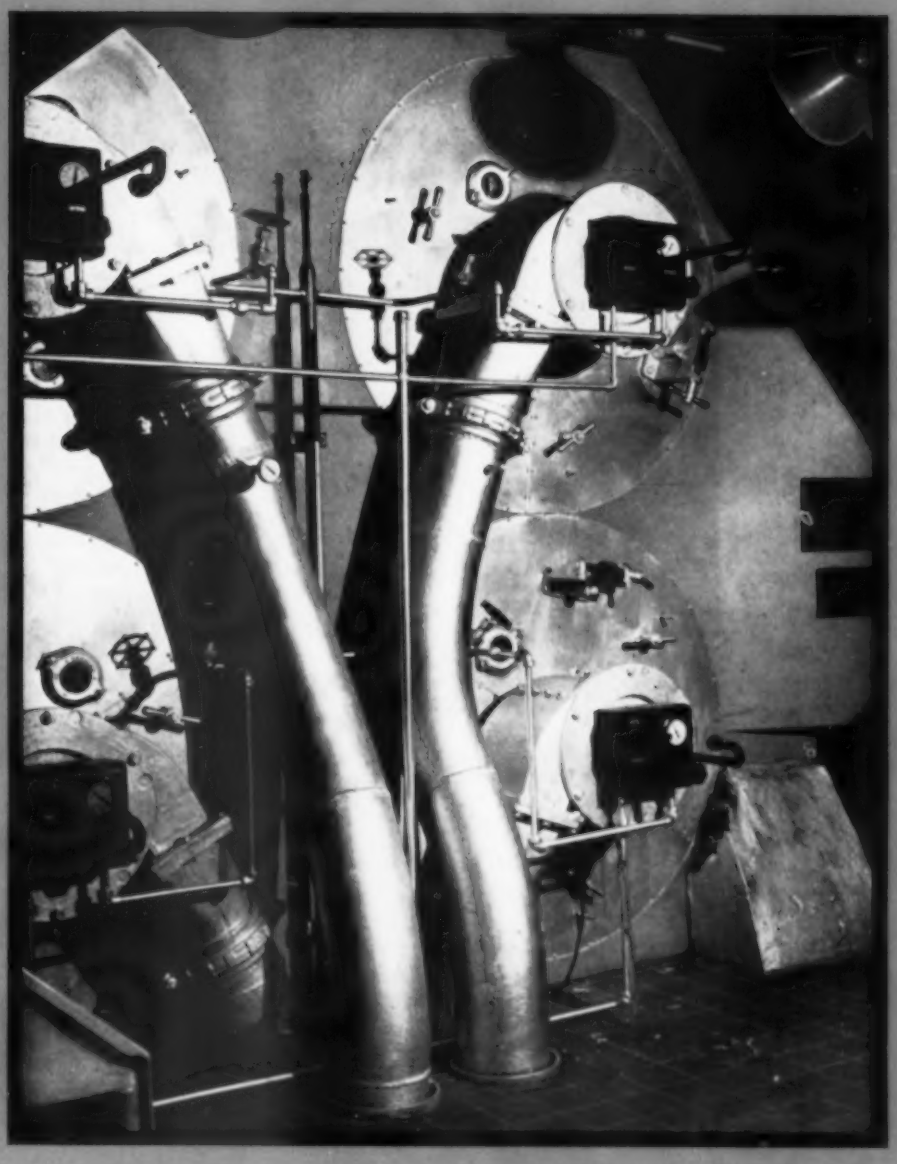


Fuel pipes and burners of unit described on page 49

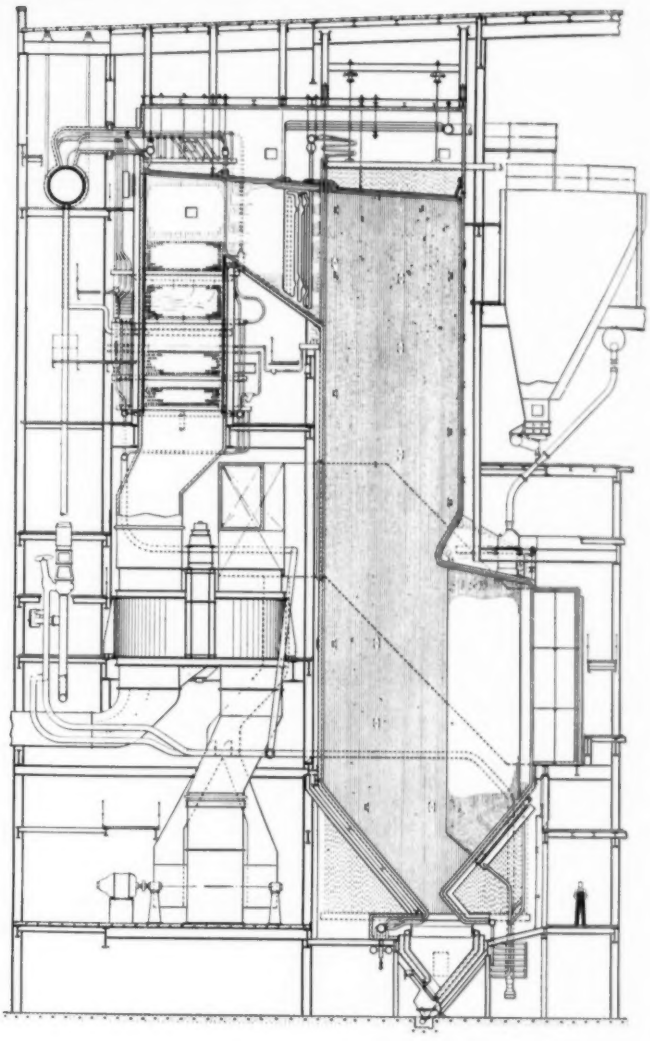
A Study of Reducing Solutions at Boiler Temperatures ›

Power Expansion Program at Nekoosa—Edwards Paper Co. ›

Turbulent Suspension Burning ›

OAK CREEK STATION

Wisconsin Electric Power Company



C-E controlled circulation boilers

The C-E Unit shown above is one of two similar units now in process of fabrication for the Oak Creek Power Plant of the Wisconsin Electric Power Company at Milwaukee, Wisconsin.

Each of these units is designed to serve a 120,000 kw turbine generator. One unit is designed for a throttle pressure of 1575 psi and the other for 1800 psi. Both are designed for a primary steam temperature of 1000 F, reheated to 1000 F.

These units are of the controlled-radiant type. Reheater surface is located in the side furnace walls and primary superheater surface forms the rear furnace wall. The secondary superheater surface is located in the first pass at the furnace outlet. Economizer surface is in the last pass of the boiler and regenerative type air heaters follow the economizer surface.

These units will be fired with pulverized coal employing the storage system with C-E Raymond Roller Mills, Type R Feeders and Type L (Vertical) Burners.

C-E

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COMBUSTION

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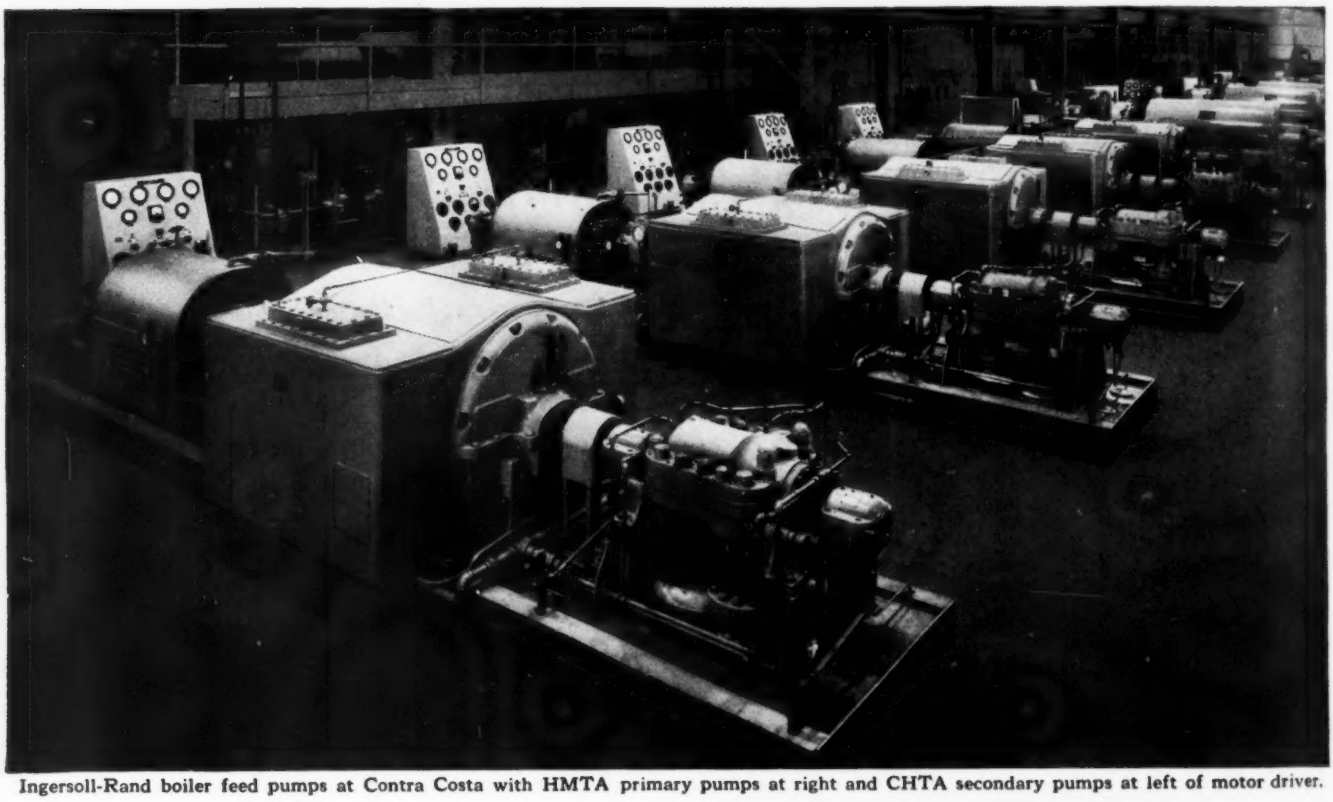
I-R PUMPS SERVE CONTRA COSTA

Pacific Gas and Electric Company's newest generating station uses Ingersoll-Rand's new Class HMTA boiler feed pumps



Ingersoll-Rand boiler feed pumps at Contra Costa with HMTA primary pumps at right and CHTA secondary pumps at left of motor driver.

The Pacific Gas and Electric Company's new and ultra-modern steam plant at Antioch, California will make available 300,000 kw to help meet the high system load of the productive Contra Costa county area. This modern boiler feed pump installation — incorporating both the new HMTA and the popular CHTA pumps — is designed to establish new standards of high pressure pumping economy.

The Contra Costa Station uses the two-pump feedwater system — each pump set carrying half the load of a 100,000 kw generating unit. The six-inch, 3-stage HMTA primary pumps, which handle 228° water at 24 psi, discharge to the low pressure heaters at 574 psi. The five-inch, 8-stage CHTA "double case" secondary pumps take 430° water at 520 psi and deliver 1310 gpm at 1990 psi. Tandem mounting permits centralized lubrication and low temperature injection from primary pump to stuffing boxes of secondary unit, which means longer packing life.

Ingersoll-Rand Class HMTA multi-stage centrifugal pumps, with advanced design and a Unit-Type rotor assembly, are available in capacities to 1600 gpm and pressures to 1200 psi. Your nearest I-R representative will be glad to give you complete information.

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Editorials

The Art of the Practical Engineer

Engineering is both an art and a science. At times it is highly practical in a down-to-earth sort of way, while on other occasions it involves abstract and abstruse theoretical considerations. In reality it is difficult and perhaps undesirable to draw a sharp distinction between the art and the science of engineering. Not only does scientific theory merge almost indistinguishably into technological practice, but also each complements and supplements the other. Most important is that these elements be present in proper balance and that engineers keep them in due perspective.

This same subject served as the title of the presidential address by Sir David Pye before The Institution of Mechanical Engineers in London last October. A distinguished engineering educator who was trained at Cambridge and was among the first engineering professors at Oxford, he has also had long experience in the several research establishments of the Royal Air Force and is now serving as Provost of the University College in London. Thus his approach to "The Art of the Practical Engineer" combines the viewpoint of both the teacher and the active research worker.

In emphasizing the importance of creativity, as distinguished from formal engineering analysis, the British educator stated that the essential positive aim of the engineer is to devise and construct something that is better for its purpose than anything previously in existence. Decrying the overemphasis on the solution of problems which are "analogous to those in engineering but different in form from those encountered in practice," he cautioned against what might be termed "the somewhat sterile pursuit of solving artificial problems in engineering, invented for examination purposes." With reference to the work of the designer of mechanical engineering equipment, he urged that engineering education include more work in design, which "calls in practice rather for the instinctive skill of the artist than for the calculations of the mathematician." He added that creative engineers have an intuitive talent which enables them to reach conclusions by other than strictly analytical processes, and that this talent may be found among skilled men in the shop and the drafting room as well as among those formally trained in the universities. In practicing the art of the engineer, Sir David Pye concluded, men are "guided by an instinct that seems to achieve a distillation of relevant experience and can be counted upon to solve a practical problem in the most direct way."

The concept that the essential aim of the engineer centers in the creation and construction of something better than anything previously in existence needs to be continually re-emphasized. If this is done, the theoretical and practical aspects of technology will fall into their proper places, and engineering will continue to be practiced as both an art and a science.

New Preferred Standards

A revision of the AIEE-ASME Preferred Standard for Large Turbine-Generators has recently been approved. This carries the maximum size of units and steam conditions beyond those specified in the 1945 Standards, namely up to 150,000 kw, 1800 psig throttle pressure and 1000 F for both throttle and reheat temperatures. Also, generator capabilities for both 15 and 30 psig hydrogen pressures are listed, in addition to the previous ratings at $^1/_2$ lb hydrogen pressure. A major change is replacement of the term "turbine capability" by "turbine rating."

It will be recalled that in the earlier days it was customary to rate the generator in kva at 80 per cent power factor, but purchasers often required that the turbine be capable of driving the generator at full kva rating with 100 per cent power factor. This was equivalent to a 25 per cent overload—a practice that still prevails for nonstandard machines.

When the earlier Preferred Standards were prescribed, they provided for a capability of only 10 per cent above nominal rating; although, of course, it is possible to obtain greater output at some sacrifice in efficiency by shutting off some extraction points.

However, use of the two terms "rating" and "capability" brought about some confusion, to obviate which the Committee decided to employ a single term "turbine rating" corresponding to the former capability value.

In general, it is the temperature of the generator windings that is a governing factor and the advent of higher hydrogen pressures opened the way to higher generator outputs. A further step has just been announced by one of the turbine builders which involves liquid cooling of hollow stator conductors for very large machines. Capacities for which such cooling is likely to be employed in the near future are beyond those covered by the present revised standards.

With the widespread employment of a single boiler per turbine it has become the practice in some circles to speak of the boiler capacity in terms of kilowatts. In doing so the revised turbine designation must be kept in mind.

Fig. 1—General view of laboratory setup

A Study of Reducing Solutions at Steam Boiler Temperatures*

Given are the results of laboratory investigations to determine the relative merits of sodium sulfite, sodium phosphite and hydrazine as oxygen scavengers in boilers operating at high steam pressures.

By HARRY D. ONGMAN

SODIUM sulfite has been used as an "oxygen scavenger" in steam boiler waters for over twenty years. Its use in lower pressure boilers has been satisfactory, but at higher pressures, above 1000 psig, a breakdown of sodium sulfite has been reported. The first phase of this investigation was carried out to establish the extent of this breakdown and the effects of the volatile products on steam purity.

Sodium phosphite has been considered as a possible substitute for the sulfite; therefore, solutions of this salt were studied in the second phase of this work.

Though no data have been published, many verbal reports have come from Germany on the use of hydrazine solutions as a sodium sulfite substitute. Hydrazine solutions were studied to answer some of the many questions left wanting after these verbal reports.

* Digest of a thesis covering graduate work at the University of Illinois and submitted in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering. The author is at present a member of the staff of the Research Department of Combustion Engineering-Superheater, Inc.

Laboratory Apparatus

The apparatus used in the laboratory work on sodium sulfite solutions can be divided into four parts. These are the feedwater system, the steam boiler, the steam and boiler water sampling system and the control system.

Since the effect of the treatment chemicals on the boiler steam purity was to be studied, it was necessary to provide a boiler feedwater of the highest quality. To obtain a high purity feed, distilled water was passed through a mixed resin demineralizer followed by deaeration in a stainless steel steam-heated scrubbing column. This method provided a feedwater with an electrical conductivity of less than 0.5 micromho. A high-pressure plunger type chemical proportioning pump was used as a boiler-feed pump.

The laboratory boiler is shown schematically in Fig. 2. The body of the electrically heated boiler was made of a seamless cold drawn steel tube 7.5 in. O.D. by 6.5 in. I.D. by 36 in. An inner shell of 11-gage steel was fitted into the main pressure shell. This inner shell was sealed at the top and extended to a point below the normal operating water level. Steam samples were taken from the inner shell. This method provided a dry saturated

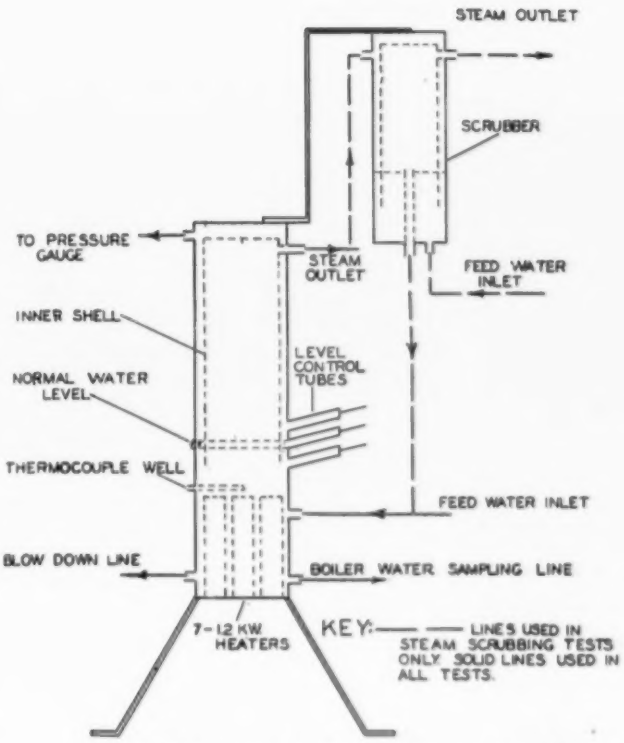

Fig. 2—Laboratory boiler with steam scrubber

sample since there was no temperature difference across the inner shell. The upper and lower ends of the outer tube were sealed by circles of $^3/_4$-in. hot-rolled steel plate welded in place. The lower headplate was provided with wells which were used as holders for the boiler heat source of seven 1.2-kw electrical cartridge heaters. Taps were provided in the boiler shell for feed inlet, steam and boiler-water sample outlets, level-control points, pressure gage and blowdown.

Description of Scrubber

The steam scrubber was similar to the boiler in construction. Steam from the inner shell of the boiler entered between the shells of the scrubber. Boiler feedwater entered at the bottom of the scrubber body and rose to the level of the over-flow standpipe. Steam from the boiler had to bubble through this head of feedwater to reach the outlet of the scrubber. Feedwater overflowed the standpipe and dropped by gravity to the boiler. The pH of the boiler feedwater was raised during the tests using the scrubber by addition of NaOH solution from a motor-driven microfeeder.

The steam and boiler-water sampling system was mounted on a table near the boiler (Fig. 3). Double-pipe stainless-steel cooling coils and pressure-relief valves were placed on the table panel. All samples were condensed and cooled at boiler pressure. The continuously flowing steam sample was metered and passed through a conductivity cell and glass electrode pH cell before exposure to the atmosphere as it passed to waste. A feed chamber on the table panel and connected into a separate feed-pump circuit was used for the batchwise addition of treatment chemicals.

Control and recording instruments were panel mounted near the boiler. Three on-off temperature instruments controlled the boiler temperature, boiler-water level and low-water cutoff. Main power relay switches were placed behind the panel and individual heater switches and heater pilot lights were mounted on the panel face. A three-point conductivity recorder and a six-point temperature recorder were also provided. Measurement of pH was made manually with a portable meter.

Procedure

After obtaining a feedwater purity of one micromho or less, the boiler was filled to operating level and enough sodium hydroxide was added to give a boiler-water pH of 10.0 to 11.5. The control system and heaters were started to bring the boiler to test temperature. Non-condensable gases were vented.

After reaching test temperature, a metered steam flow of 10 lb per hr was started and 0.1 to 1 gram of reagent grade sodium sulfite was slug fed to the boiler. Control readings were made every fifteen minutes and analytical samples of steam and boiler water were taken every hour.

Runs were of four to thirty hours duration and the boiler was maintained as a non-flow system at test temperature between daily runs. Runs were made at saturated steam temperatures of 400, 450, 500, 550, 600 and 636 F.

Tests with the steam scrubber in the system were made in the same manner except that the microfeeder was filled with sodium hydroxide solution and started after sufficiently pure feedwater had been obtained. During these runs the feedwater pH was checked hourly. Runs with the scrubber were made at saturated steam temperature of 600 and 636 F.

Sodium sulfite concentrations in boiler-water samples were determined by a standard indirect iodometric titration. Reducing matter in the steam was determined by direct titration with standard potassium iodate solution and was reported as ppm SO_2. Tests for sulfide ion were made at all test temperatures by the methylene blue method.

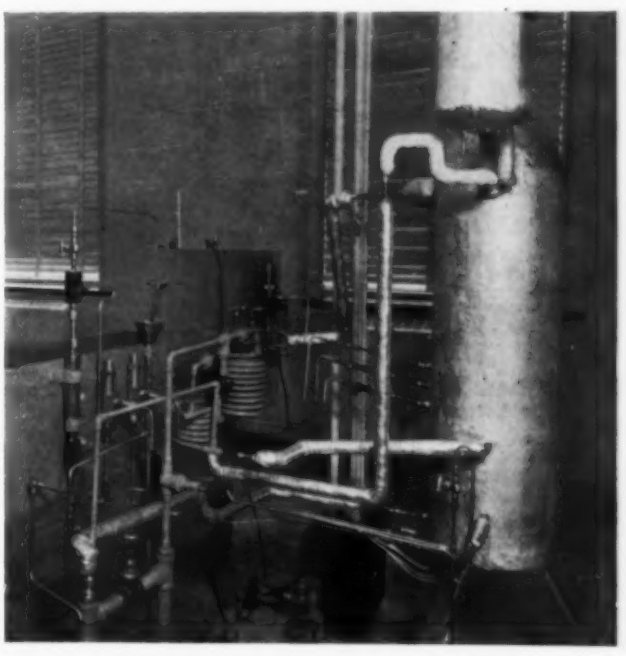

Fig. 3—Steam and boiler-water sampling system

Discussion of Results

The general effects of a lower steam pH and a higher steam conductivity due to an increase of boiler-water sodium sulfite concentration are noted at all test temperatures. The curves of Fig. 4 show the magnitude of these changes for a saturated steam temperature of 600 F. The general shape of these curves is typical of curves obtained at all test temperatures. Curves for the other temperatures were plotted and used to provide the values which are plotted in Fig. 5 as summary plots. Sample data for only one test at 600 and 636 F are given, but the curves of Fig. 5 are based on the data from a number of runs at every test temperature.

No hydrogen sulfide was detected in the steam from any run; however, measurable quantities of sulfur dioxide were present at test temperatures of 550 F and above. The changes in steam pH and conductivity noted above are to be expected in the presence of sulfur dioxide. Data from central steam generating stations using sodium sulfite treatment show very good correlation with these results. Though no measurable quantities of SO_2 were present in the steam of runs at 500 F and below, it is reasonable to assume, on the basis of the data obtained, that the same breakdown of sulfite ion to sulfur dioxide did take place.

In the final series of tests at 600 and 636 F the steam stream was scrubbed with the incoming boiler feedwater. The feedwater contained enough NaOH to give a pH of between 8.3 and 10.0. Since there was no sodium sulfite in this feed, the dilute NaOH solution provided a good

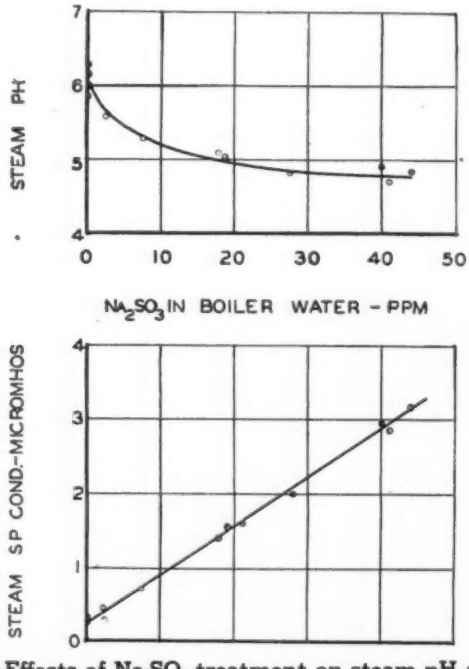

Fig. 4—Effects of Na_2SO_3 treatment on steam pH and conductivity at saturation temperature of 600 F

scrubbing medium for sulfur dioxide. A plot of ppm SO_2 in the steam versus ppm Na_2SO_3 in the boiler water is shown in Figs. 6 and 7 for tests at 600 and 636 F, respectively. In both of these plots, curves are shown for conditions with and without steam scrubbing.

Sodium sulfite is used in steam boilers to remove any dissolved oxygen in the feedwater by the following reaction:

$$O_2 + 2Na_2SO_3 = 2Na_2SO_4 \quad (1)$$

However, the results of this study indicate that not all of the sodium sulfite entering a steam boiler is utilized in this reaction or reactions with metallic oxides. Much of the sulfite ion is broken down and leaves the boiler as sulfur dioxide. This vapor pressure of sulfur dioxide over a

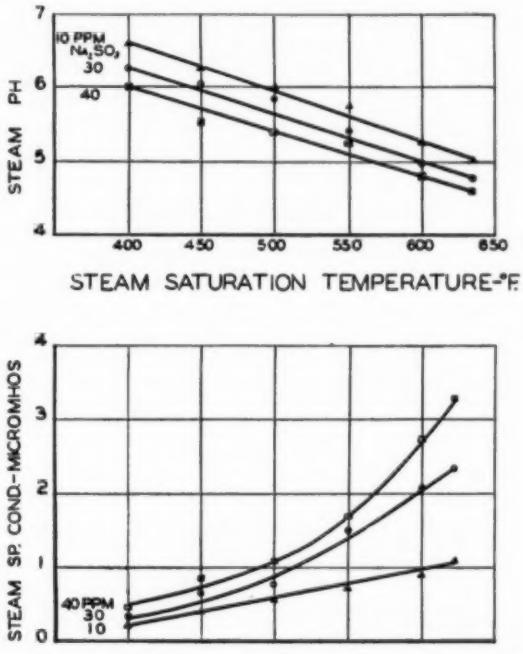

Fig. 5—Effects of Na_2SO_3 in boiler water on steam pH and conductivity at all test run temperatures

very dilute alkaline solution of sodium sulfite can be explained by considering the following equations:

$$Na_2SO_3 + 2H_2O = 2NaOH + H_2SO_3 \quad (2)$$

$$H_2SO_3 = H_2O + SO_2 \quad (3)$$

The sulfur dioxide moves with the steam to the point of steam condensation and the equilibrium point of equation (3) shifts to the left. The resulting low pH causes corrosion in the wet stages of an operating steam turbine. In the vacuum of the turbine condenser, equation (3) shifts slightly to the right and the resulting sulfur dioxide is discharged from the cycle with the non-condensable gases.

Na_2SO_3 Test Data

Temperature 636 F Pressure 2000 psia Boiler water pH = 10.8 at 27 C
Na_2SO_3 treatment = 800 mg. Without Steam Scrubbing

Time from Na_2SO_3 Addition in Hours	Sp. Cond. of Steam in Micromhos at 25 C	pH of Steam at 23 C	Ppm Na_2SO_4 in B. W.	Ppm SO_2 in Steam
0	0.84	5.3	0	0.00
1	3.37	4.6	41	...
2	2.45	4.7	31	0.780
3	1.66	4.7	21	0.430
5	0.95	5.0	5	0.160
6	0.83	5.0	2	0.097

Na_2SO_3 Data

Temperature 636 F Pressure 2000 psia Boiler water pH—10.4 @ 27C
With Steam Scrubbing

Feed pH @ T C	Ppm Na_2SO_3 in B. W.	Ppm SO_2 in Steam	Steam Sp. Cond. in Micromhos @ 25 C	Steam pH @ T C
9.5 @ 29	46	0.343	3.28	4.9 @ 21
9.6 @ 29	29	0.126	1.28	5.4 @ 21
9.6 @ 29	13	0.056	1.20	5.3 @ 21
9.6 @ 27	26	0.138	1.32	5.3 @ 19
9.9 @ 30	55	0.780	2.20	5.0 @ 21
9.9 @ 30	15	0.034	0.82	5.5 @ 21
9.9 @ 30	10	0.000	0.78	5.5 @ 21
9.6 @ 27	39	0.335	2.34	4.8 @ 20
9.5 @ 28	48	0.417	3.42	4.8 @ 20

Study of Sodium Phosphite Solutions

LABORATORY APPARATUS

The boiler used for this phase of the work was the same as that used by F. G. Straub in his studies of sodium phosphate hide-out (*Trans.* ASME, Vol. 72, pp. 479–89, 1950). This boiler provided a heat input rate of about

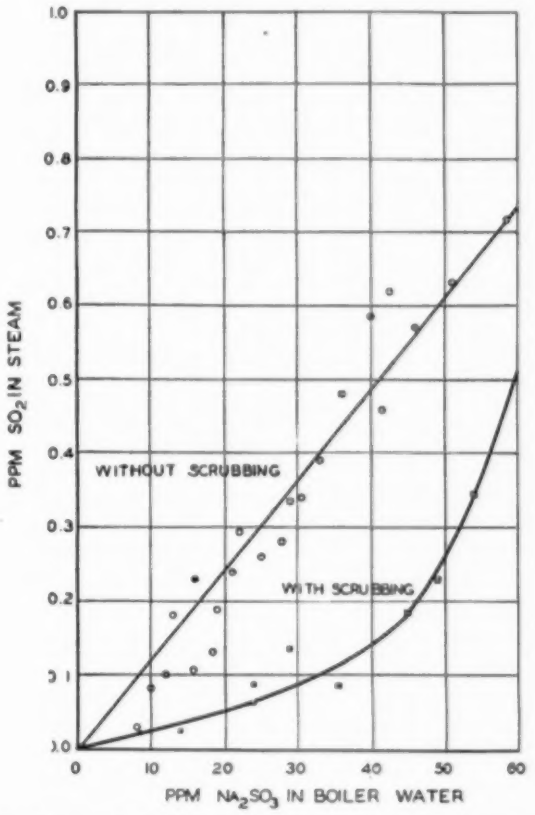

Fig. 6—Effect of NaOH scrubbing on steam SO_2 content at 600 F

60,000 Btu per hr per sq ft of inside tube area and had the additional advantage of allowing study of the heating surface after the test. All other components of the system were the same as in the sodium-sulfite tests.

PROCEDURE

Tests in this series were run with no steam flow. After the boiler temperature had stabilized on on-off control, 2 to 15 grams of technical grade sodium phosphite was slug fed to the boiler. Control readings were made every fifteen minutes and analyses for sodium phosphate and sodium phosphite were made hourly. Runs were made at saturated steam temperatures of 500 and 600 F.

Phosphate ion was determined colorimetrically by the ammonium vanadate method. This test is specific for phosphate ion and is unaffected by the presence of phosphite ion.

Total phosphate was determined by the same method on a separate sample after oxidation of the phosphite ion with mercuric chloride. Phosphite ion concentration was then obtained from the difference of the two phosphate concentrations.

Discussion of Results

In the first test at 500 F the boiler was initially filled with deaerated water and any non-condensable gases trapped in the boiler were vented. This venting was done after heating and before the phosphite was added. Under this condition of near zero initial oxygen concentration, it was expected that the reaction, $PO_3 + {}^1/_2O_2 = PO_4$, would remove any remaining trace of oxygen and then stop. The slow decrease in phosphite ion and corresponding increase in phosphate ion indicated another reaction, but the rate was too slow to indicate what this reaction might be. The constancy of the total phosphorous-containing ions when expressed on the basis of the phosphite ion indicated that no dilution or concentration was taking place due to leaks in the system.

In the test at 600 F the rapid oxidation of the phosphite ion with gas formation indicated the following reactions at the heating surface:

$$Fe_3O_4 + Na_3PO_3 = 3FeO + Na_3PO_4$$
$$3Fe + 4H_2O = Fe_3O_4 + 4H_2$$

In this reaction series, the protective coating of Fe_3O_4 on the heating tube surface was reduced and was washed from the metal surface. The freshly exposed iron then reacted with steam to produce hydrogen gas and more Fe_3O_4 to sustain the sequence of reactions. This analysis of the possible reactions is substantiated by the flammability of the evolved gas and the etched appearance of

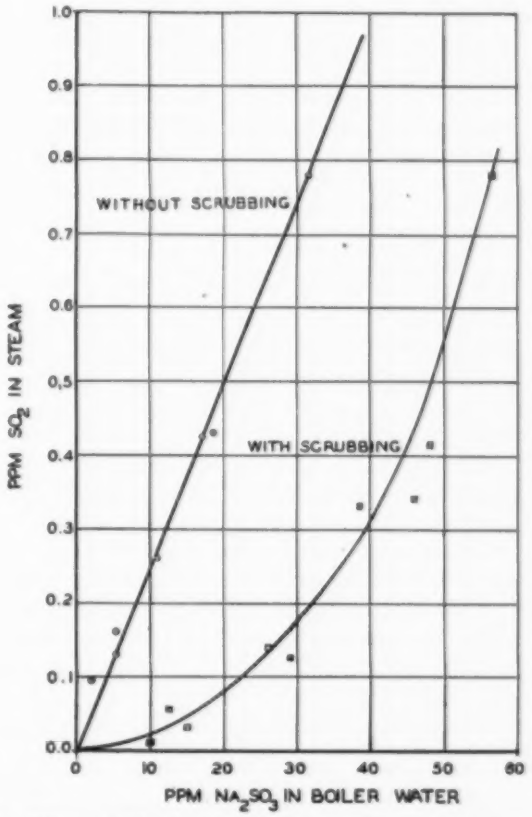

Fig. 7—Effect of NaOH scrubbing on steam SO_2 content at 636 F

the heating tube surface. The tube surface showed no oxide coating and offered the appearance of an acid-treated steel surface.

Study of Hydrazine Solutions

LABORATORY APPARATUS

The equipment used was the same as that used in the

sodium sulfite tests except that the steam scrubber was not used in any of these runs. The microfeeder was used in the higher temperature runs to give a continuous feed of hydrazine along with the feedwater to the boiler.

In the final test of this series, the high heat input rate boiler of the phosphite tests was used.

Procedure

In the first series of runs at saturated steam temperatures of 350, 450 and 500 F, hydrazine was slug fed at the start of each test to give an initial boiler water concentration of 50 ppm. A commercially available 22 per cent hydrazine solution was used for this addition.

A continuous feed of hydrazine from the microfeeder was used in the higher temperature series. This addition was controlled to give a concentration of 1.5 to 3 ppm of hydrazine in the feedwater. At this low feed rate, boiler water concentrations were maintained low enough to suppress excessive ammonia formation. Saturated steam temperatures of 500, 550 and 600 F were run in this series.

The high heat rate boiler was used for a no-flow constant heat input test at 600 F. Temperature of the boiler was controlled by directing an air stream over an exposed portion of boiler shell.

Steam and boiler-water samples were analyzed hourly in all runs. Ammonia was determined by direct Nesslerization after oxidation of the hydrazine in samples of condensed steam. A variation of the indirect iodine method was developed for the determination of hydrazine and though it was somewhat complex the results were found to be accurate as well as reproducible to 0.05 ppm of hydrazine.

Discussion of Results

In every test with the steaming boiler the steam pH and conductivity increased after hydrazine addition. Since hydrazine has a low boiling point, the vapor pressure over the boiling water solution is high and thus the pH and conductivity of the steam increased. The slug feed runs showed a steady decrease of steam pH and conductivity with boiler water hydrazine concentration decrease.

The continuous feed tests provide a practical method of hydrazine addition for high-pressure steam boilers. In an operating boiler, hydrazine in the steam stream would partially return to solution in the turbine condenser. This recovery in the condenser would reduce the chemical makeup to the boiler.

The increase in pH due to hydrazine and ammonia in the steam would be beneficial in reducing turbine-blade corrosion. Hydrazine would provide the additional advantage of maintaining reducing conditions throughout the steam-water cycle. The breakdown of hydrazine to ammonia offers a disadvantage if the concentration increase in a recycle system became excessive. Very high ammonia concentrations cause corrosion in copper or copper alloy components when present in a power plant cycle.

The heating tube was removed from the high-heat-rate boiler after six days operation at 600 F. The total hydrazine treatment was 7.7 grams as N_2H_4. The interior tube surface was in excellent condition. No etching or cutting had taken place, and the surface was covered with a thin layer of brownish black deposit. This deposit was typical of that noticed in sodium-sulfite-treated boilers. The quantity of this material was too small for analysis, but from physical appearance the deposit seemed to be a mixture of Fe_3O_4 and Fe_2O_3. The gases vented after the hydrazine addition had a strong odor of ammonia. The high ammonia content of the vented gases was further evidence of the reaction:

$$3N_2H_4 = N_2 + 4NH_3$$

The black color of the deposit indicated the reaction:

$$6Fe_2O_3 + N_2H_4 = 4Fe_3O_4 + N_2 + 2H_2O$$

In all tests high-grade deaerated feedwater was used; therefore, the reaction of hydrazine was reduced to a minimum. The effectiveness of hydrazine as an "oxygen scavenger" should be studied now that these tests have shown no adverse effects on steam boiler metal surfaces.

Conclusions

1. An appreciable vapor pressure of sulfur dioxide exists above dilute alkaline solutions of sodium sulfite in a high-pressure steam boiler.
2. The concentration of sulfur dioxide in the steam above a sodium sulfite solution can be greatly reduced by scrubbing with boiler feedwater of pH 8.0 to 10.0.
3. Sodium phosphite is too strong a reducing agent to be useful in a steam boiler. At a temperature of 600 F, the reduction of the protective ferric oxide film at the heating surface results in tube metal attack and hydrogen evolution.
4. Solutions of hydrazine oxidize to give ammonia and nitrogen at temperatures above 350 F. This oxidation is in addition to the distillation of the hydrazine with the steam. Hydrazine solutions reduce Fe_2O_3 to Fe_3O_4 at high temperature steel surfaces, but this reduction is not harmful such as the reduction encountered with sodium phosphate solutions.

Acknowledgement

The material presented here is based on a thesis submitted in partial fulfillment of the requirements for degree of Master of Science in Chemical Engineering in the Graduate College of the University of Illinois, 1952. The laboratory work reported was done in the Engineering Experiment Station at the University of Illinois, under the direction of Prof. F. G. Straub, on a program sponsored by the Utilities Research Commission of Chicago, Ill.

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Boiler Construction Costs

By HERMAN WEISBERG, Mech. Engr.
Public Service Electric & Gas Co.

The history of construction costs of power plants, and particularly boilers, is reviewed in the following which formed one part of a Panel Discussion at the 1952 ASME Annual Meeting. It is brought out that as a result of design progress comparable construction costs, adjusted for the increases in price of materials and labor, as well as improvement in fuel efficiency, have steadily decreased. It is suggested that in order to combat rising prices, the size of future units continue to be increased, and their efficiency improved.

A DISCUSSION of the cost of boilers alone without regard to the effect on total plant costs is meaningless. It matters not if boiler costs increase as long as the total power plant cost is not adversely affected; or else, performance is improved to justify the increase, as for instance in the case of reheat. The boiler plant, including its portion of the building, accounts for approximately fifty per cent of the total power plant cost.

Fig. 1 shows the Handy-Whitman Indexes of the cost of materials and labor entering into the cost of power plants. Plotted are the indexes for the total power plant, the boiler plant, and the boiler proper, using the 1912 level as 100 per cent. Roughly, power plant cost indexes doubled after World War I; increased another sixty points between World Wars I and II; and doubled again since World War II; the present level being over five times that of 1912. These indexes reflect the cost of material and labor to produce a given design, and are not intended to include technological progress. Although the base boiler index increased more rapidly than either of the other indexes, the boiler plant index, which includes associated equipment and erection costs as well as the boiler, followed the total power plant index closely.

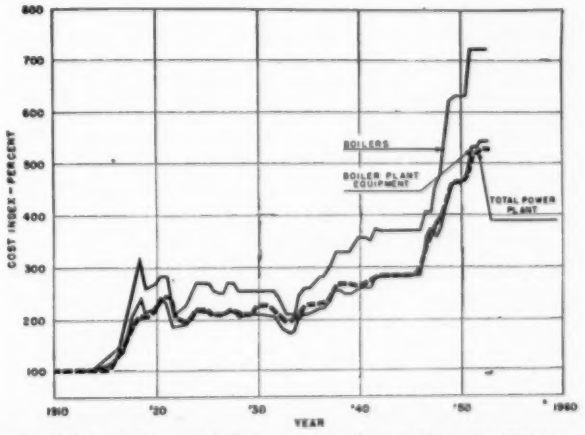

Fig. 1—Materials and labor cost indexes (Handy-Whitman)

In Fig. 2 the total power plant index is replotted and extended, based on assumed escalation of mild proportions, to 1954 when current projects will be completed.

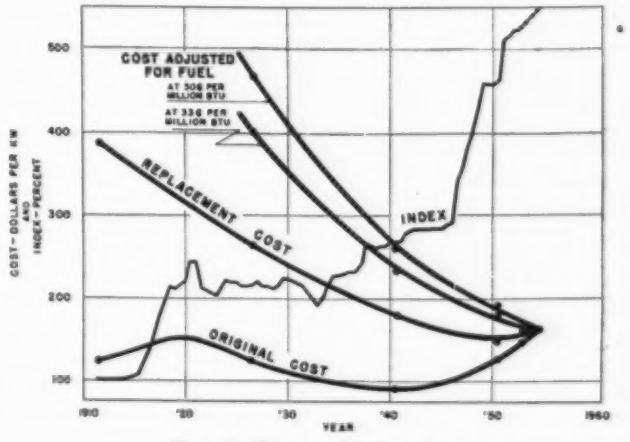

Fig. 2—Power plant costs

The bottom line of this figure shows the actual and estimated original costs of power plants installed since 1912 on one system, which may be considered as typical. It will be noted that original costs have varied, and are now at a level only about fifty per cent higher than in 1912, in spite of the precipitous 5 to 1 rise in prices. Costs are plotted against the year of initial operation of the particular plant, although expenditures for subsequent units after the first and miscellaneous improvements made since the initial installation are included in the cost. Now, if the price indexes, at the time the expenditures were made, are applied against these original costs, we arrive at replacement costs as shown by the second curve; a steadily descending curve which levels off in more recent years. It will be noted that a plant of 1912 design, built today, would cost just under $400 per kilowatt; as compared to $160 for a plant of the latest design.

The steady reduction in replacement cost per kilowatt has been accomplished despite more costly materials and equipment to improve efficiency (see Fig. 3), through the use of higher steam pressures and steam temperatures, reheat, and other advances. The present-day design, however, consumes only one-third the fuel of the

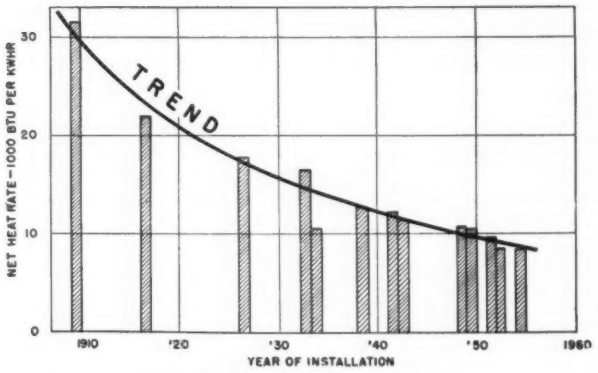

Fig. 3—Trend in heat rates

1912 design; and that in itself accounts for considerable reduction in cost, not only because of less fuel to be handled but also the reduction in circulating water requirements, and many other items which result in a physically smaller plant.

While this trend of reduction in heat rate is diminishing, considerable gains are still being made with each succeeding installation, as shown by the plot in Fig. 4. It will be seen that the 1953 design involving 2350 psig, 1100 F with 1050 reheat, shows an improvement of more than six per cent over the 1951 design of 1500 psig, 1050 F, 1000 F. The gain, however, is not all due to the difference in steam conditions, but also to improved boiler and turbine efficiencies.

Going back to Fig. 2, capitalizing the difference in heat consumption of the various installations, we arrive at an adjusted cost as shown by the top two lines; the lower of which is based on present fuel cost, and the upper on the assumption that the fuel cost will increase over the life of the unit at the same rate as it has in the past. Capitalization of the fuel cost differences is based on a sixty per cent capacity factor. If the older units are utilized for standby or peak-load purposes only, as they usually are, the capitalized value of the difference in fuel consumption approaches zero and these adjustments do not apply. The top lines, therefore, represent the equivalent costs of the various designs of power plants, based on present day prices and adjusted for differences in heat rate, using the present cost as a base. The trend has been continuously downward, and reflects the technological progress that has been made. The area between the replacement cost and the top lines represents the gain

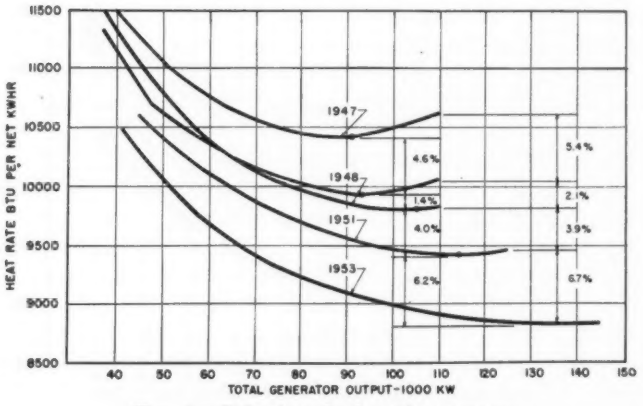

Fig. 4—Calculated plant heat rates

due to increase in fuel efficiency; and that between the replacement cost line and the 1954 estimated cost of about $160 per kilowatt represents the gain due to other design progress. This latter includes increase in size of units, reduction of the number of boilers per unit, reduction in spare boiler capacity made possible by greater reliability as a result of design improvements, installation of equipment outdoors, and many other changes.

Further improvement not reflected in this plot is the reduction of operating and maintenance manpower, as shown in Fig. 5. Installations now under construction will operate with as few as one man per 3000 kw; as compared to one man per 500 kw for the 1912 design; or a 6 to 1 ratio.

The reduction in building volume enclosure per unit output is shown in Fig. 6. Much of this improvement is due to the size factor, but the reduction in boiler room enclosure is largely due to installing major portions of the boiler outdoors.

One of the principal factors in reducing costs is the increase in size of units. Fig. 7 is a plot of the progress

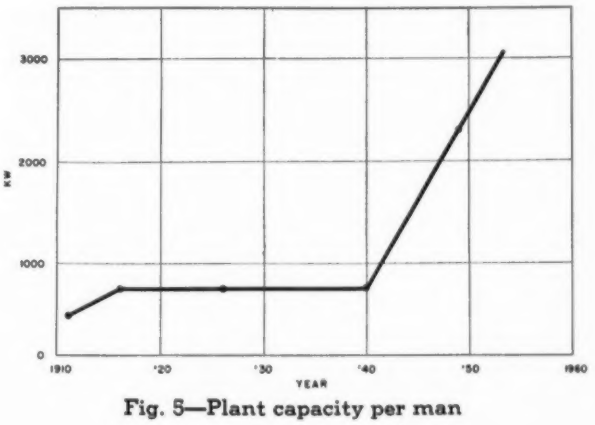

Fig. 5—Plant capacity per man

which has been made in this direction. The curve shows the increases in system peak load, read on the scale at the right. The plotted points indicate the size of units installed, read on the scale on the left, which is ten per cent of the scale on the right. It will be noted that in general the points fall near the curve, indicating that the size of units has followed the peak load increase over the years. The figures in parentheses indicate the number of boilers per turbine unit, which is now at the irreducible minimum of one per unit.

Notwithstanding skyrocketing prices, therefore, it has been possible to hold the cost of the total power plant to reasonable increases principally by increasing the size of the installation, reducing the number of boilers and spare boiler capacity installed, reducing the building enclosure, and making many minor improvements. Several of these measures have been carried as far as is possible, and the benefits from others are following the law of diminishing returns.

Fortunately we have in this country a healthy competitive situation between manufacturers of boilers, as well as associated auxiliary equipment, and as a result further improvements are constantly being proposed. Size and efficiency will continue to increase. The rate of improvement must, however, await the development of larger equipment, including auxiliaries, as well as more economical materials for higher temperature operation.

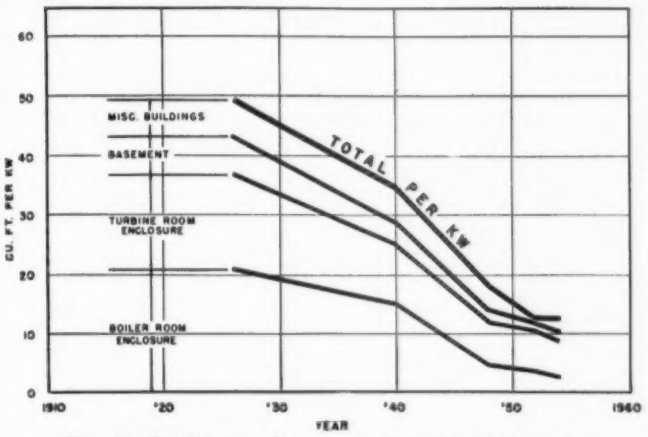

Fig. 6—Building volumes per installed kilowatt

Design improvements offered by the manufacturers, such as cyclone furnaces; controlled circulation; pressure firing; gas recirculation; various forms of radiant steam heating surface; improved burner and furnace arrangements; and many other innovations will be evaluated as time goes on.

For further betterment of performance there are being considered at this time measures for increasing steam temperatures to 1200 F, increasing pressures to above the critical, providing two stages of reheat, lowering boiler exit gas temperatures, and many other improvements. Because of the size of units being installed, radical changes must be considered with caution. For instance, the next step in steam pressure will eliminate the boiler, as there is no longer a boiling point. This means that any contamination which enters the system from condenser leakage, evaporator carryover, or simply corrosion or erosion of the piping and equipment itself, can no longer be concentrated in the boiler and blown down, but must either cycle around or deposit out on the heating surfaces or turbine blading. Considerable research to determine the solubility of the various elements in steam and water over the temperature range of the cycle, and possibly a pilot plant may be necessary to determine the feasibility of such an installation before it can be incorporated in a full size unit.

In conclusion, the answer to the question "What can be done to offset the continuously rising costs of material and labor," particularly in connection with boilers, is, as in the past, the installation of larger units commensurate with load build-up and the availability of larger equipment; and the installation of more efficient and improved equipment consistent with technological developments.

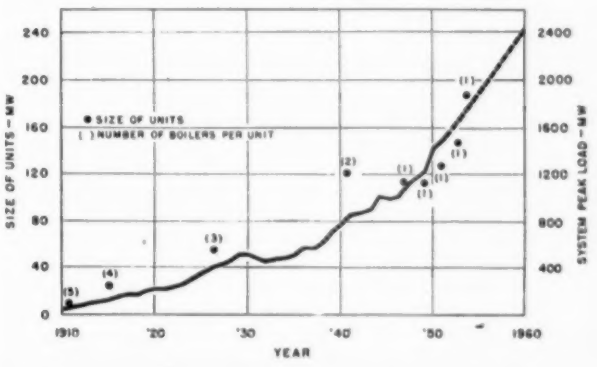

Fig. 7—System peak load and size of generating units

Engineer Shortage Discussed

Some three hundred top-level industrialists and technical educators listened to suggestions concerning the shortage of trained engineers at the Fifth College-Industry Conference held at the Northwestern University Technological Institute, Evanston, Illinois, on January 31.

Titus G. LeClair, manager of engineering for the Commonwealth Edison Company and the Public Service Company of Northern Illinois, considered our greatest waste in engineering talent to lie in requiring an engineer to handle all the details of his job. The obvious answer to this problem, as he saw it, is to relieve the engineer of paper work and other non-technical activities by giving him the help of a technical assistant who might be a graduate of a technical school or have had one or two years in such a school.

Appealing to employers to adjust their organizations to absorb this type of individual, Mr. LeClair asserted that the graduate engineer could thereby increase his working effectiveness at least 10 to 15 per cent and become better satisfied. By the same token the assistant who didn't have the opportunity to acquire or complete a college education is happy to have the chance to work with the engineer who can help in his further training.

Following along this idea, Professor K. W. Wendt of the University of Wisconsin believed that one answer to the present problem lies in a substantial expansion of the technical institute field.

E. W. Seeger, vice president of Cutler-Hammer Inc., speaking from the viewpoint of the registered professional engineer agreed that the best immediate solution for the present shortage is better utilization of the engineers now available; but he cautioned that if the number of engineering aides and technicians is materially increased, we should be certain that they are properly classified so as not to jeopardize the progress already made in the recognition of engineering as a profession.

C. E. Deakins, dean of students at Illinois Institute of Technology stated that each year the nation needs, for replacements alone, some 30,000 new engineers; but next June the colleges are expected to graduate only 24,000, with the number declining to 19,000 in 1954 and to 17,000 in 1955. He urged that there be earlier identification of engineering aptitudes and interests among secondary school students, and that industry increase its scholarship funds for talented students, many of whom are now lost to industry because they cannot afford an engineering education.

"Because of the already serious shortage of engineers," said Dean Deakins, "industry and the colleges must impress upon our selective service officials the great tragedy that will befall our future national security and welfare if they strip the engineering schools of a large part of their student body."

Don P. Reynolds, representing the ASCE, noted that starting salaries of young engineers and those at the peak of their profession are generally adequate, but that there are many extremely productive men in the middle brackets who have become discouraged and embittered by failure of recognition and compensation to keep pace with the relative value of their professional efforts.

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Power Expansion at Nekoosa-Edwards Paper Co.

By FRANK H. COLDWELL

Manager of Mill Power, Nekoosa-Edwards Paper Co.

A review of the growth in steam and power demands over the past forty years at the Port Edwards and Nekoosa mills and how they have been met, leading up to the recent installation at the latter plant, which is described in some detail.

THE Nekoosa-Edwards Paper Company has been manufacturing paper for over 60 years. Its main offices are at Port Edwards, Wis., with mills at both Port Edwards and at Nekoosa, Wis. It is situated on the Wisconsin River, and in the early days its power was received from the power sites at Port Edwards and Nekoosa and transmitted to various pieces of equipment by shafting, belts and pulleys. The only steam power used was from engines driving paper machines where the steam could be used for paper drying, and some steam engines for mechanical power where water power could not be transmitted.

As time went on the plants grew, and electric power became common in the industry. About 1913, a power site on the Wisconsin River at Centralia was obtained where 2000 kw[1] of hydroelectric generation was installed, and a 1000-kw steam turbine was purchased for Port Edwards. The power sites on the Wisconsin River at Port Edwards and Nekoosa were still used primarily for mechanical power, and for the production of ground wood pulp used directly in the paper process.

Later, additional paper machines were installed to bring the capacity of each plant up to four paper machines each. Changes in the paper industry and the products of the company eliminated the use of mechanical pulp made by grinding wood with water wheels; this pulp being replaced by chemical pulps. As this trend progressed, the Port Edwards and Nekoosa power sites on the Wisconsin River were converted to production of hydroelectric power. Under this condition in the early 20's, two steam turbines were installed to stabilize the power output of the hydroelectric plants under varying river conditions. In 1929, the first 400-psi boilers were installed at the Port Edwards plant, together with a turbine-generator exhausting at 150 psi back pressure to obtain by-product power.

[1] Later increased to 3600 kw capacity.

As power demands grew, additional boilers and a 3500-kw turbine-generator were installed at the Nekoosa plant, with the turbine extracting steam at 150 psi and exhausting at 30 psi back pressure. This was the status of the property in 1950 when plans were made for a new paper machine and the expansion of pulpmaking facilities at the Nekoosa mill, necessitating a large block of power. At this time the average electrical load had reached 13,000 kw, made up largely of hydro and by-product steam power, with some mechanical water power still being used for the driving of stock preparation equipment for the paper machines.

At that time the boiler house of the Nekoosa mill had one 450-psi pulverized fuel Combustion Engineering VU boiler rated at 110,000 lb. per hr, one C-E chemical recovery boiler of similar design characteristics and five low-pressure boilers which served as standby for the pulverized coal boiler and were used mainly for the disposal of waste wood.

Basic Data

The basic data indicated that the power expansion program should be sufficient to care for an increase in production at the Nekoosa plant from 156 tons to 200 tons of pulp per day and an increase from 140 tons to 253 tons of paper per day. No expansion of the Port Edwards mill was contemplated and no increase in steam or electrical demand at that plant was assumed. The plan as set up was designed to facilitate the installation of future equipment.

The paper industry uses large amounts of steam in process requirements. Hence, by-product electrical power is possible so the plant was designed to produce the maximum amount of this power possible. Since coal is relatively expensive in the plant area, it was decided to continue the use of pulverized coal in order to utilize the extremely small size coal available at lowest prices. Accordingly, refinements in methods of soot blowing, burner arrangement, and both coal and ash handling were incorporated in the boiler design to facilitate use of this type of coal.

The steam necessary at the Nekoosa mill alone was studied but as the power system depended on three sources of hydroelectric power, substantially augmented by two sources of by-product steam power, the electrical needs were studied as an overall system.

Boiler Equipment

Loading diagrams were prepared to show the maximum required steam loading upon which a new boiler size might be selected. This was based upon the steam load for the maximum month, minimum average hydro generation over the last ten years, peak electrical loads on the entire system, and maximum capacity of the chemical recovery boiler unit which existed under the new conditions.

The resulting steam loading indicated that approximately 75,000 lb. per hr of additional steam would be necessary, and since the existing 475-psi pulverized-coal-fired boiler was normally loaded to full capacity most of the year an additional boiler of the same size was selected. This would allow some easing of the loads on the existing boiler, duplication of equipment and permit some additional growth.

This size boiler could be located in the area presently occupied by two of the existing five low-pressure boilers, and by retaining the other three, it is expected that during a period of roughly six or eight weeks in mid-summer, loads will be such that one of two large 475 psi boilers could be out of service for periods of necessary overhaul and maintenance.

Because of the necessity for additional electrical power, temperatures and pressures other than the 475 psi, 700 F total temperature were investigated. This investigation indicated that because of the lack of condensing power, the additional investment would not pay off.

Accessory Equipment

The existing plant deaerator and condensate-return system was inadequate for the then existing plant. Only about $3^1/_2$ min storage of feedwater was available and it was felt that this condition would be intolerable. Loading studies indicated an average load of 300,000 lb an hour of steam would be required under winter conditions in this locality, and accordingly a new deaerating heater and storage tank was installed. The dearating heater was designed for a capacity of 400,000 lb per hr, and the storage tank to hold 75,000 lb of water or roughly 15-min supply under average loading conditions.

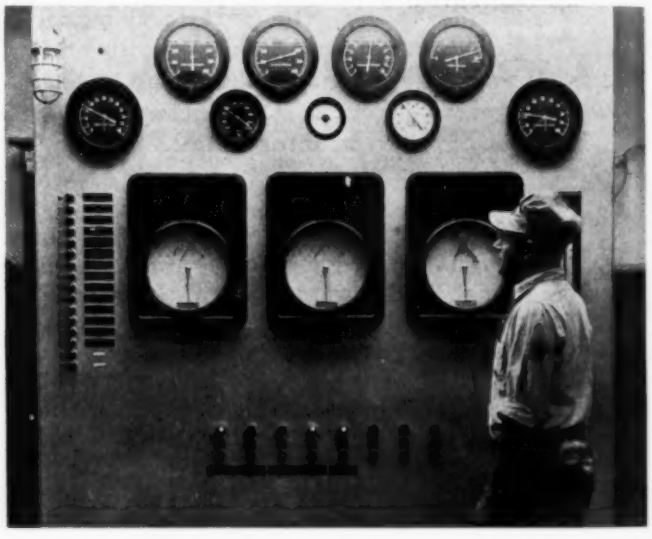
One new boiler feed pump, steam-turbine driven, was purchased for use during winter heavy load conditions. The steam turbine will supply, in connection with trap returns from the process, continuous blowdown system, and other sources of waste steam, just about enough exhaust steam to meet feedwater heating requirements. Any additional steam required for this purpose will come from the 30-lb steam system through a reducing valve. It is contemplated that one of the existing smaller feedwater pumps will carry the plant load during the larger part of the summer season, or the two in parallel will carry the loads in the winter season. This will always leave one or more feed pumps idle, ample time being provided for maintenance and standby capacity.

The coal-handling stystem, continuous blowdown equipment, ash-handling equipment, combustion control, feedwater regulation, ventilation, coal scales and feedwater treatment are, in general, extensions of the existing systems. The installation of the equipment and clearing of the site involved the removal of two stoker-fired boilers, their coal bunkers, removal of their induced-draft fans, ductwork, and relocation of an existing bucket elevator which was in front of the stoker-fired boilers.

The latter boilers were then equipped with a small coal silo, and the existing bucket elevator adapted for use with this silo. Further adaption was made to transfer coal from the old bucket elevator to the new bunkers supplying the two large pulverized-coal-fired boilers. This was done in order to provide two methods of getting coal from the car to the main boiler coal bunkers, permitting maintenance on any of the coal-hoisting equipment at any time and thereby promoting continuity of operation.

New Turbine

The steam loading diagrams showed the maximum required steam loading upon which a new turbine size might be selected. Conditions of minimum hydro generation over the past ten years, minimum steam requirements over the calendar year, maximum steam available from wood refuse (which reduces by-product power available from turbine extraction), no steam flow to dryers of paper machines but full power required to keep paper machines running, and peak electrical loads on the system were considered. The important by-product power, previously discussed, was always receiving utmost consideration. Finally, studies of electrical power requirements of the new paper machine and pulp requirements were superimposed upon the electrical loads of the existing system to determine the total electrical requirements.



Steam operating panel for the new turbine-generator

Under worst conditions it was considered that 6400 kw would be required for the expansion program. Accordingly an 0.8 power factor 6000-kw turbine-generator was selected with extraction at 30 psi pressure although this size provides no expansion for future growth conditions. However, variations in river flow conditions should provide ample time for planned maintenance and overhaul periods so that the equipment can be kept in best condition for low-water periods.

Load studies further indicated that condensing power

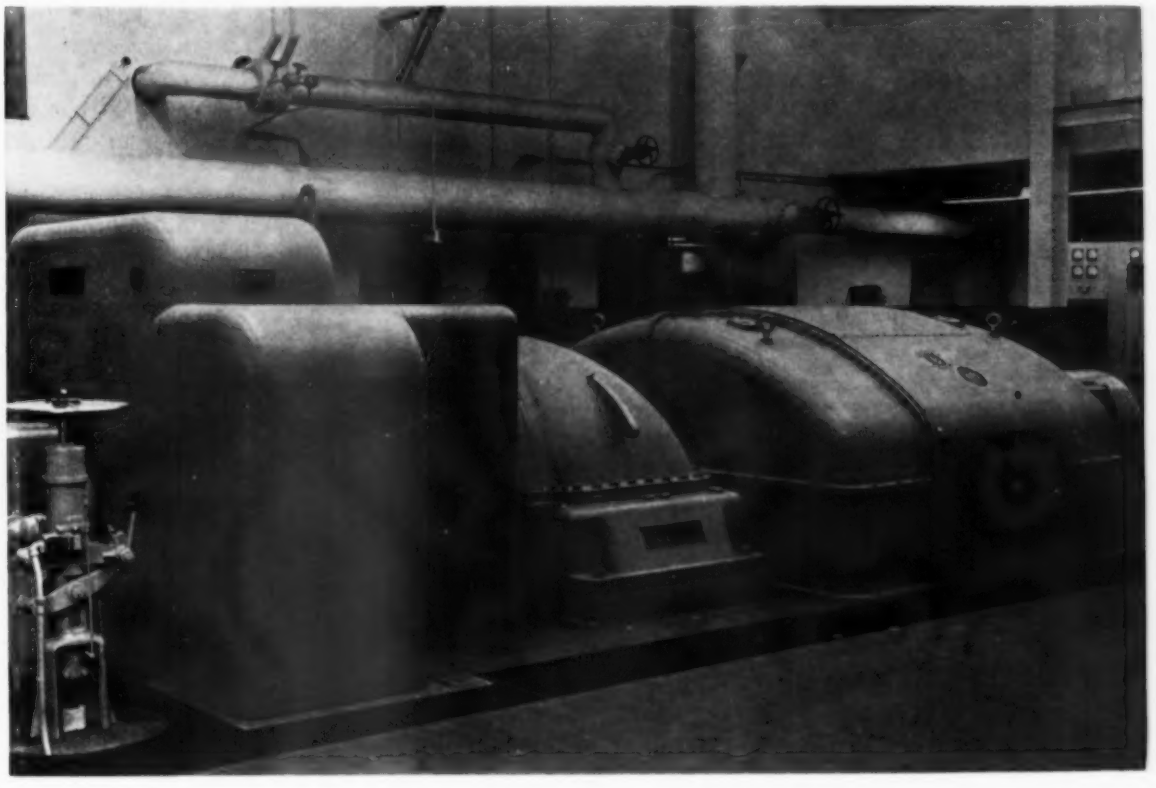
would be needed only an average of five months of the year; during the remaining time the condenser would be run at minimum load. Due to the fact that the turbine would be run only at times when extraction loads would be available, and that the expected average condenser load would only be 2000 kw, a condenser with capacity to operate under 4 in. of vacuum at full load was selected. Two half-capacity circulating water pumps and two half-capacity condensate pumps were selected in order to save power under high extraction conditions.

Electrical Equipment

The new addition of the new block of power provided by the turbine-generator called for a complete review of the electrical connections between the various plants. These are connected by a 15,000-volt system originating at the 3600-kw Centralia Plant connecting with the Port Edwards mill hydro and steam plant and thence to the Nekoosa mill hydro and steam plant. The new 6000-kw generation indicated that the interrupting capacity of the 15,000-volt switchgear at most locations was inadequate. This was particularly so at the Nekoosa plant and it was decided that at this plant a complete revision was necessary.

A new three-phase outdoor 7500-kva transformer was installed between the existing 15,000-volt line and the new turbine room. The existing 480-volt mill distribution bus was split in order to add safety to the existing distribution switchgear and a new three-phase, 2000-kva, 15,000/480-volt transformer was installed. New 15,000-volt air-break metal-clad switchgear was purchased for the transformer installations mentioned, as well as for existing 15,000/480-volt transformers and 1500/2300-volt transformers. All of the foregoing are rated 500 mva interrupting capacity and will be ample for a long time to come. Existing inadequate size switchgear at other plants is presently being studied with view to replacement on a planned program covering a number of years.

A new 2300-volt distribution center was set up in the turbine room distributing to the boiler plant, new paper machine, and tied back through the 7500-kva transformers, previously mentioned, into the old system. This should add stability to the system, particularly the new paper machine, in case of trouble on tie lines between plants or at other plants.



New 6000-kw turbine generator

Power is distributed to the paper machine at both 2300 and 480 volts, all paper machine motors over 200 hp operating at 2300 volts and smaller sizes at 480. The boiler room is provided with a 2000-kva 2300/480-volt transformer load center, and complete metal-clad motor-starters are used operated by remote control from the boiler operating panelboard. The paper machine and the 2300-volt motor starters are all of the latest metal-clad type, with provisions for remote starting and stopping of motors from panels strategically located in the paper-machine room for convenience of operation. Two 1500-kva 2300/480-volt transformer load centers are provided for the 480-volt motors in the paper machine and stock preparation rooms. All motor starters operating at 480 volts are also of the latest metal-clad type with similar remote operation as noted. This equipment is all housed in separate rooms with pro-

vision for expansion of circuits. These rooms are provided with forced ventilation, featuring self-cleaning filters for maximum cleanliness.

Paper Machine Prime Mover

The paper machine proper, which consists of the four-drinier wire section, a main bank of 5-ft diameter by 178-in. long dryers, a secondary bank of 4-ft diameter by 178-in. long dryers, calendars, paper reels and other equipment, is driven by a 400-psig 700-F multi-valve multi-stage turbine and reduction gear, set into a basement lineshaft. This turbine is rated at 1000 hp which is sufficient to operate the machine when producing paper at 1500 fpm.

The turbine is expected to operate at a range of speeds from roughly 1500 to 4200 rpm. depending on the paper being manufactured. Special governing equipment is supplied, which will maintain the turbine speed constant at any point, plus or minus 0.2 of one per cent, or maximum variation in paper speed of about 6 ft per minute.

The turbine operates under a constant back pressure of 30 psig, exhausting into the extraction line connected with the 6000-kw turbine extraction and the exhaust of the 3500-kw turbine. Economy studies indicated that the additional cost of a multi-valve multi-stage turbine to drive the paper machine over that of a single-valve, single-stage machine was highly profitable due to the additional power produced on the main generating units by the increased amount of 30 psig extraction or exhaust steam which they would supply.

Engineering design and construction were carried out by Chas. T. Main, Inc., Boston, Mass., in cooperation with the Engineering Department of the Nekoosa-Edwards Paper Company.

Principal Equipment Involved in Nekoosa-Edwards Paper Co. Power Expansion Program

STEAM GENERATING EQUIPMENT

Boilers	Combustion Engineering - Superheater, Inc., 110,000-lb per hr continuous (125,000 lb for 2 hr). 700 F T.T., 475 psig.
Air preheater	C-E tubular two sections 18,500 sq ft.
Pulverizers (two)	C-E 4 burners. 11,000 lb per hr each on midwestern coal.
I. D. Fan	American Blower Corp. 83,500 cfm @ 11.8 in w.g. 375 F, 860 rpm outlet damper.
F. D. Fan	American Blower Corp. 43,500 cfm @ 9.5 in. w.g. 100 F, 1170 rpm, inlet vane damper.
Magnetic coupling	Electric Machinery Mfg. Co. for i. d. Fan.
Magnetic coupling	Electric Machinery Mfg. Co. for i. d. Fan.
Pulverizer and fan motors	Electric Machinery Mfg. Co.
Dust collector	Western Precipitation Corp.
Soot blowers	Diamond Power Specialty Co., two retractable in screen tubes, two retractable side wall blowers, ten stationary.
Water columns	Diamond Power Specialty Co.
Safety valves, valves, etc.	Manning, Maxwell & Moore, Edwards, Crane.
Coal-handling equipment	Stephens-Adamson Co. "Redler" vertical and horizontal conveyor, reciprocating feeder, crusher, Syntron vibrator.
Car shaker	National Power Equipment Co.
Combustion control, steam meters, etc.	Bailey Meter Co.

POWER GENERATING EQUIPMENT

Turbine-generator	Elliott Co. 6000 kw, 0.8 pf, 3600 rpm, 400 psig, 700 F, 30 psig extraction pressure.
Condenser	Worthington Corp. 4500 sq ft horizontal two-pass divided water box.
Circulating pumps (two)	Worthington Corp. 2500-gpm double-suction, centrifugal, 1200 rpm.
Condensate pumps (two)	Worthington Corp. 150 gpm, center-suction, centrifugal, 1200 rpm.
Air Ejectors (two)	Worthington Corp. 108 sq ft.

FEEDWATER EQUIPMENT

Feedwater heater	Cochrane Corp. Spray-tray type, 400,000 lb per hr.
Boiler feed pump	Ingersoll-Rand 375,500 lb per hr 592 psig discharge, 3550 rpm.
Boiler feed pump turbine	Elliott Co. 3550 rpm, 360 hp, 400 psig, 700 F inlet, 5 psig back pressure.
Water treatment (three)	Infilco, Inc., split-stream hydrogen zeolite, 450 gpm maximum rate.
Chemical feed pumps	Dearborn Chemical Co.

MISCELLANEOUS EQUIPMENT

Liquid level equipment and reducing valves	Fisher Governor and Cochrane Corp.
Feedwater controls	Bailey Meter Co.
Desuperheaters (three)	Swartwout Co.
Makeup pumps (two)	Goulds Pumps, Inc., 350 gpm, 150 ft head.
Turbine room crane	Industrial Equipment Co., 15 ton, 1 hook.
Ventilating equipment	American Blower Corp.
Coal Scales (two)	Stock Equipment Co.
Oil filtration system	Bowser, Inc.
Paper-machine turbine	Worthington Corp., variable speed to 500/4500 rpm, 1000-hp, 400 psig, 700 F t.t., 30 psig back pressure, multi-stage, multi-valve, direct-connected to double-helical speed-reducing gear, 3940/500 rpm, Woodward governor.

ELECTRICAL EQUIPMENT

15-kv switchgear	Westinghouse Elec. Corp. 15 kv, 1200 amp, 500 mva interrupting capacity.
5-kv switchgear	Westinghouse Elec. Corp. 5 kv, 2000 amp, 250 mva interrupting capacity.
2400-volt motor starters	General Electric limit amp control.
480-volt motor starters	Cutler-Hammer "Unitrol," fused combination starters.
Outdoor transformer	Westinghouse Elec. Corp. 7500-kva, 15-kv/2400 volt 3-phase, 60-cycle.
Unit substations (two)	General Electric 1500-kva, 2400/480-volt with 3-AL-2-50 800–1200 amp secondary breakers.
Unit substations (two)	General Elec. 2000-kva, 2400/480-volt with 2-AL-2-50, 1200 amp and 1-AL-2-75 secondary breakers.
2400-volt bus duct	Westinghouse Electric Corp. 15-kv, 2000-amp duct.
480-volt bus duct	Bulldog Electric LoX duct in 800 amp and 1200 amp sizes
Cable trays	Cope cable trays—6, 12 and 18 in.
Station control battery	Exide Manchex, 60 cell, General Elec. Phano-charger 12½ amp.

Consulting Engineers—Chas. T. Main, Inc., Boston, Mass.

Turbulent Suspension Burning

By OTTO DE LORENZI*

The following discusses improvements in the burning of wet bark and wood-room refuse either separately or in combination with coal, oil or gas by employment of a high-set traveling grate spreader stoker, employing the principle of flash drying. The text is adapted from a talk by the author before the Alkaline Pulping Division of the Technical Association of the Pulp and Paper Industry at Mobile, Ala., in November, 1952.

FLASH drying may be briefly described as a process in which wet material is dispersed in a stream of heated gas, under suitable conditions of particle size and temperature differential, so that a major portion of the moisture is flashed into vapor and carried off by the gas stream.

A paper by this author presented at the 1949 Semi-Annual Meeting of the ASME in San Francisco stated: "Use of the two-stage furnace, comprising a Dutch-oven and a secondary combustion chamber, has been generally accepted as a standard for hog fuel and other kinds of wet-wood refuse. Recently, however, large-scale experimental installations of the single-stage furnace using both underfeed and spreader firing have been operated successfully. As a result of these developments, there are now available, for many types of installations, simplified combustion systems, having high inherent capacity, to which automatic controls may be easily applied." Since this was written, however, spreader applications have found almost universal favor, and underfeed designs have been discarded.

For a conventional spreader-stoker installation the distributors are located in the front wall at an elevation of from 3 to 4 ft above grate level. Flight of fuel from distributor to grate is quickly completed over a relatively short and flat trajectory. Some of the smaller particles are carried upward by the gas stream and thus never reach the grate. The major portion of the fuel, however, has hardly started through drying and devolatilization stages before it reaches the fuel bed. With this arrangement only a limited amount of moisture is flashed into vapor, and thus a greater part of drying and practically all of the combustion process actually takes place after the fuel comes to rest on the grate. This characteristic of the conventional spreader installation makes it necessary to supply practically all air for combustion through the grate and thereby limits the amount which may be used overfire for producing furnace turbulence or for effecting fly ash return. Furthermore, if there is any erratic or slug feeding, particularly with high-moisture fuels, partial quenching of the bed will immediately follow these periods of heavy feed. During intervals between slugs the fuel bed will gradually brighten, as drying and devolatilization of the fresh charge progresses. Operating results under these conditions are somewhat less favorable than where continuous controlled feed is used.

High-Set Feeders

To take full advantage of flash-drying effect in a spreader installation, it is necessary to increase the time for flight of fuel through the furnace atmosphere. This can be accomplished by locating the feeders at an elevation of from 12 to 20 ft above the grate level. Inasmuch as a major portion of the burning will now occur throughout the furnace cavity, it becomes necessary to rearrange distribution of the air supply so that a much larger percentage is made available above the fuel bed. Nozzles for this increased overfire air supply are best located in the four furnace corners below the feeders. With this arrangement it is possible to use large fuel particles, because they are spun around in flight by the high velocity streams and retained in the rising column of burning gas for a greater length of time before coming to rest at grate level. It is this increased time of flight through the hottest furnace zone that causes: moisture to be quickly flashed into vapor; partial or complete devolatilization of the fuel to take place; and residual combustible constituents to become ignited before reaching the grate. Slug feeding produces no noticeable changes at fuel-bed level, consequently there are no adverse effects on operating results. This arrangement of feeders and overfire air has changed materially the operating characteristics of spreader stokers by producing real turbulent suspension burning.

Turbulent suspension burning may therefore be defined as the principle of showering relatively large particles of solid fuel downward, from some considerable height in a towerlike furnace, through relatively large

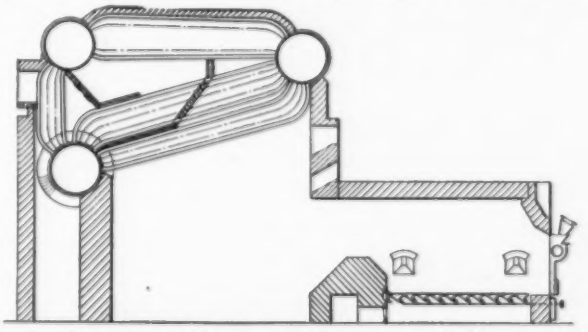


Fig. 1—Spreader stoker applied to an existing two-stage furnace for plywood mill in British Columbia

* Director of Education and Fuels Consultant, Combustion Engineering-Superheater, Inc., New York, N. Y.

quantities of highly turbulent gas and overfire air to effect: flash drying; partial or complete devolatilization; ignition of fuel constituents; and finally, uniform distribution of the residual fuel to the grate surface, in the lower furnace zone, where combustion is completed through reduced percentages of undergrate air.

Since 1949 the majority of new installations that use some form of wood or cellulose fiber refuse, as primary fuel, are spreader-stoker equipped. These steam generating units employ single-stage furnaces without arches of any sort. Furnace walls are water-cooled so as to minimize refractory exposure and thereby reduce sintering of ash and sand, with the result that in-service time between maintenance shutdowns is extended materially.

In some instances older two-stage furnaces, employing cone or pile burning, have been changed over to spreader firing by installing suitable distributor units and grates in the original Dutch ovens. Relatively thin and level fuel beds replace the previously used piles, with a resultant speed-up in responsiveness to changes in steam demand, as well as increased burning capacity.

One of the earliest successful installations for spreader stoker burning of wet-wood refuse with a wide variation in size consist was in a British Columbia plywood mill. In this instance the original steam generating plant consisted of three bent-tube boilers, two rated at 440 hp and one at 368 hp, all equipped with Dutch-oven furnaces for pile burning. The small unit was changed by installing a single spreader distributor. The original grate, 7 ft wide by 10 ft long, was replaced with one 4 ft 6 in. by 10 ft. A sectional side elevation of the revised unit is shown in Fig. 1. The fuel is an indeterminate and continuously varying mixture of bark, slivers, chips, shavings, and sawdust from salt-water-driven fir and hemlock. Moisture varies from 50 to 65 per cent. The comparative continuous capacities are 17,500 lb of steam per hour from the smaller spreader-equipped unit with a net grate area of 45 sq ft, and 20,000 lb of steam per hour for the larger cone-burning unit with a net grate area of 120 sq ft.

In another West Coast installation the conversion from pile burning to spreader firing is illustrated by Fig. 2. In this instance the grate is 17 ft 6 in. wide by 9 ft 2 in. long, having an effective area of 160.4 sq ft. The secondary combustion chamber is partially water-cooled and a live-bottom surge bin, using a chain-type feeder, is installed to assure control of fuel feed. The fuels include dry planer shavings, green planer shavings, fir hog, sawdust, cedar hog, hemlock hog, bark and pulp bark plant and chipper refuse. These vary in moisture from perhaps 8 to 70 per cent and in size from sawdust to coarse cedar hog.

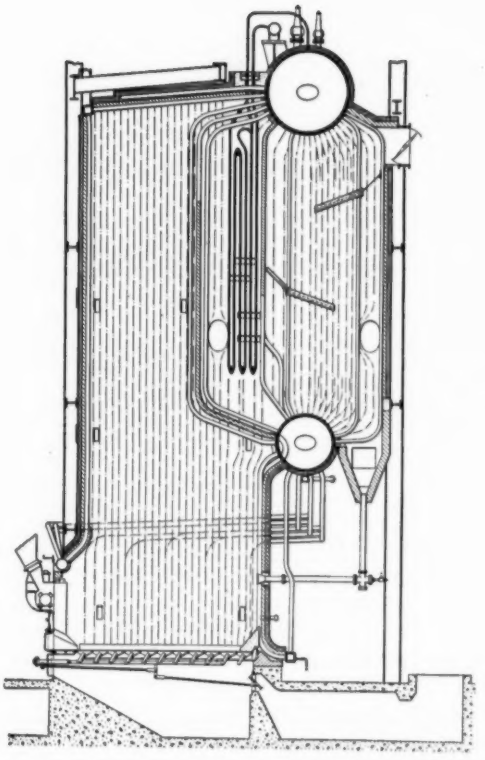


Fig. 3—A West Coast installation for burning wet-wood refuse from a lumber mill

Experience gained with this unit (Fig. 2) has resulted in the installation of several other spreader-equipped steam generators using water-cooled single-stage furnaces similar to that shown in Fig. 3. A heat-release rate of 24,500 Btu per cu ft of furnace volume and 720,000 Btu per sq ft of grate are used for guaranteed maximum continuous capacity. The fuel generally is sawmill refuse composed of sawdust, planer shavings, and hogged bark, along with other wood refuse. Some of the limits encountered are 10 to 70 per cent sawdust, 30 to 60 per cent planer shavings, and 0 to 50 per cent hogged fuel. Where logs are salt-water borne, furnace-wall deposits will usually result from salt and marine encrustations picked up during transit from forest to mill. With fresh - water - borne logs these deposits are either

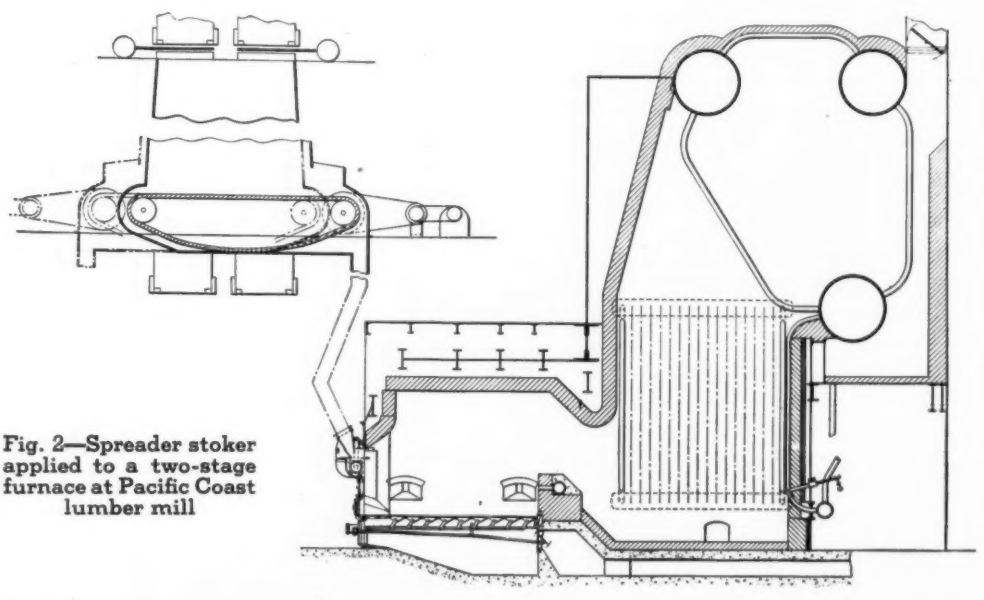


Fig. 2—Spreader stoker applied to a two-stage furnace at Pacific Coast lumber mill

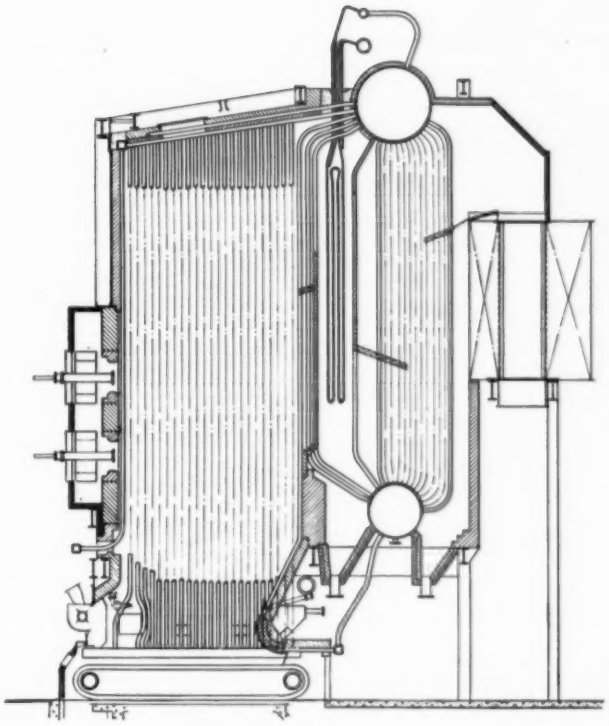


Fig. 4—Unit in a southern paper mill burning wood-room refuse and natural gas

of a minor nature or in some cases entirely absent.

Some time ago a southern paper mill installed a single-stage unit, Fig. 4, for a maximum continuous capacity of 90,000 lb per hour with wood-room refuse and 150,000 lb per hour with either natural gas or a combination of natural gas and wood. An actual capacity of 115,000 lb per hour has been easily maintained with wood refuse containing 45 per cent moisture. Wood supply to the four spreader distributors is regulated through a live-bottom surge bin. Overfire-air jets, angled slightly downward through the rear wall, provide added furnace turbulence. Use of air at 350 F is of considerable assistance in the successful operation of this unit at 115,000 lb of steam per hour with a corresponding grate release rate of 880,000 Btu per sq ft per hour. The foregoing installations all use spreader distributors set in a conventional manner. Distribution is solely dependent on speed and adjustment of this mechanism as influenced by size consist of the fuel used. Designs of this type are indicated for plants in which size of steam generating units lie below 70,000 to 80,000 lb per hour, or where it is desirable for economic reasons to produce steam at lower efficiency, or where the unit also serves as an incinerator for any overproduction of non-salable refuse.

First IIigh-Set Spreader

During the early part of 1946 an experimental steam generating unit, Fig. 5, was placed in service for a southeastern naval stores plant. It included a single-stage furnace in which spreader distributors were raised from the conventional elevation of 3 or 4 ft to a point approximately 19 ft above grate level. Provisions were made for supplying all or part of the air for combustion through tangentially directed nozzles located in the zone below distributor level and above the grate. This unit was, therefore, the first application of the principle of turbulent suspension burning as defined in the early part of this paper.

The fuel differs somewhat from ordinary wood refuse in that it is a by-product to a process in which old pine stumps are first given a preliminary spraying with water to remove part of the sand and soil carried by the roots. After this rinse the stumps are passed through a series of high-speed chippers. The resulting chips then enter cookers where steam is used to remove practically all the resins and pitch. The spent-wood chips, devoid of the flashy ignition characteristics of pine, are then burned to produce steam for process requirements.

Design of this experimental unit was projected for a steam capacity of 70,000 lb per hour. The furnace is 10 ft wide, and active grate area is 123 sq ft. Furnace height is 32 ft above the grate. Side walls and rear wall are partially water cooled. Overfire-air nozzles are arranged for four alternately rotating tangential belts to provide the swirling and highly turbulent zone through which the fuel must travel on its flight to the grate. Air for combustion is actually obtained from three main sources: underfire, at room temperature, through the stoker grate by furnace-draft induction; overfire from the air heater, by the forced-draft fan, to furnace nozzles; and leakage through distributor units as well as around stoker seals. A live-bottom bin is used to regulate the flow of spent-wood chips to the distributors.

This unit has now been in commercial service for over six years during which some changes have been made to improve operating characteristics. Design capacity was easily exceeded to the extent that 100,000 to 125,000 lb of steam per hour is now normal operating procedure, with CO_2 ranging between 16 and 18 per cent, and smoke of approximately No. 1 Ringelmann density. During one series of tests a capacity of 142,000 lb of steam per hour was maintained for 3 hr, with CO_2 averaging 18.4 per cent, when burning spent-wood chips having a moisture content of 37.0 per cent and a heating value of 5600 Btu per pound as fired.

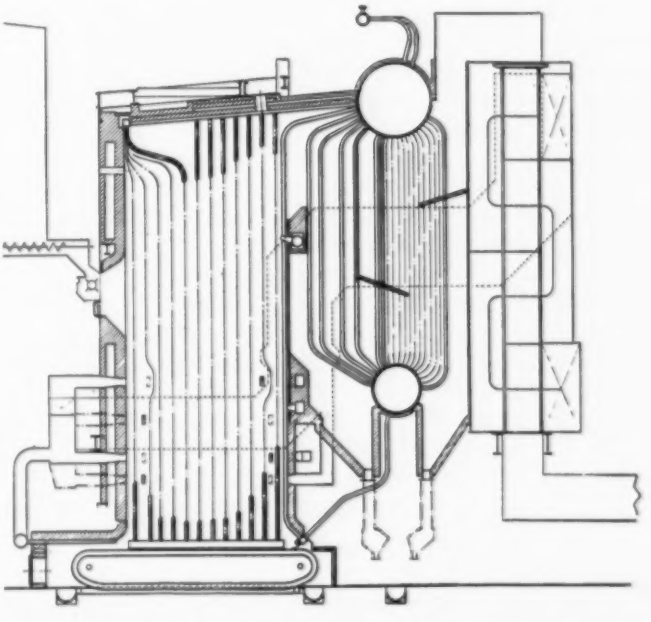


Fig. 5—Large-scale experimental unit for turbulent burning spent wood chips in a naval stores plant

Tests and operating experience with this unit have provided much fundamental data from which newer designs were developed. One of the most important factors established was the conservative continuous "apparent" grate-liberation rate of approximately 1,000,000 Btu per square foot per hour. This rate is conservative because it can be exceeded by a wide margin without distress of any sort. The word "apparent" is used because the liberation rate represents all fuel entering the furnace, even though a large portion of its heat content is released in the turbulent zone above the grate. Several units of a similar type are now in various design stages, under construction, or in regular plant service. The cellulose type fuels to be used are from paper mills, saw mills, sugar mills, naval stores plants, and furfural producing plants. In addition, one unit will operate solely on either low- or high-volatile coal. A number will also be equipped for burning oil, natural gas, or coal, either separately or in combination with the wood.

One of these newer units, Fig. 6, installed in a large eastern paper mill, has now been in continuous service for over twenty months. During this period there have been only seven outages of short duration. One of these resulted from failure of a magnetic-coupling bearing, one from general plant operating difficulties, two for adjustments and correction of expansion clearances, and three for inspection during holiday shutdown of the entire mill. Design capacity is 90,000 lb of steam per hour at 430 psi and 613 F when burning pine bark containing 40 per cent moisture. A capacity of 100,000 lb per hr was also guaranteed for coal and fuel oil. Forced- and induced-draft fans, however, were provided for an output of 150,000 lb per hour, in the event the unit possessed the high capacity indicated by experience with the test unit shown in Fig. 5.

The fully water-cooled tower-like furnace has a height of 44 ft from top of grate to underside of roof. Furnace volume is approximately 6200 cu ft. Distributors are located 17 ft above the grate level and 17 ft 9 in. below the lower edge of the entrance into the first boiler pass. The stoker grate is 13 ft wide and has a gross area of 192 sq ft. Air for combustion is available at temperatures up to 550 F, and the undergrate air supply may be tempered to 350 F through use of a bypass damper. At design capacity, with wood fuel, furnace liberation rate is 19,600 Btu per cu ft per hr, and grate heat release rate is 610,000 Btu per sq ft. Predicted efficiency is 75.0 per cent.

The tangential overfire-air nozzles are in the furnace sidewalls between the distributors and top of grate. In addition, two rows of horizontally opposed nozzles are located 18 in. above the front and rear ends of the stoker. A third row of horizontal nozzles is placed in the rear wall at an elevation of 13 ft above grate level. Four sets of tangential oil burners, with intermediate air nozzles, are installed in the side walls, approximately 3 ft 6 in. above the distributor level. Overfire jets, in addition to supplying the larger portion of air for combustion, are also used to distribute the residual fuel. Thus the distributors throw fuel into the furnace, where it is then swirled around and spread out by these jets and then uniformly deposited on the grate.

A large live-bottom surge bin is located in front of the unit above distributor level. Sixteen helicoid screws discharge the feed to four distributors. Inasmuch as coal may also be burned, these screws are driven by four variable-speed motors having a speed range of 50–1 to assure positive feed control.

A multi-tube dust collector is installed between the air-heater outlet and induced-draft fan inlet. The fly ash reinjection system returns all collected carryover to the lower part of the furnace through four nozzles in the rear wall and two in the side walls. In the original concept of turbulent suspension burning, it was assumed that the use of extreme turbulence in a tall furnace would produce no more fly ash carryover than obtained with conventional spreader firing. Many tests have shown this to be a correct assumption, even though 100 per cent reinjection is used.

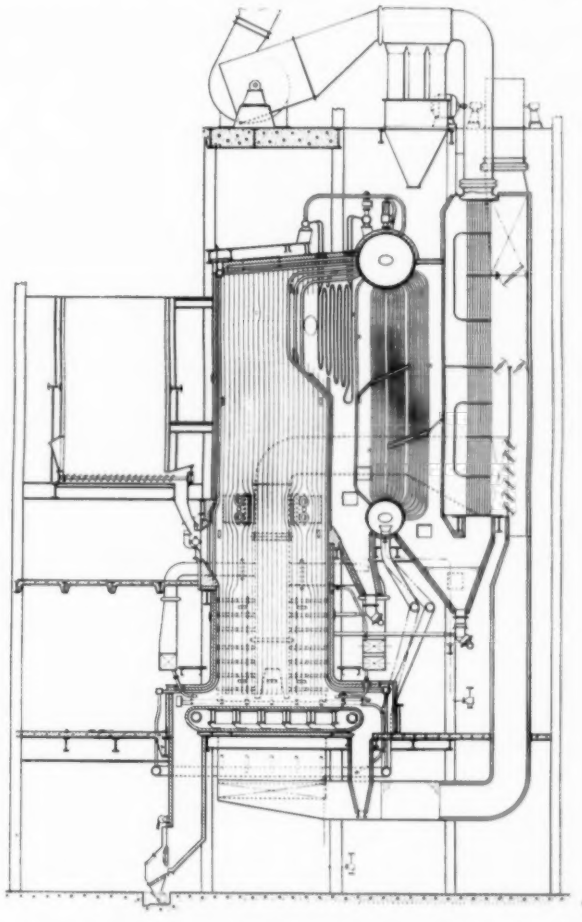


Fig. 6—Unit employing turbulent suspension burning of wood-room refuse, coal and oil

At present the wood-room of this mill is operated sixteen hours per day, and no storage area is provided for excess wood-refuse production. Consequently, this refuse is burned at the rate at which it is produced, except for some over-run which is used to provide a full bin to carry the unit, at reduced load, over the daily eight-hour wood-room shutdown period. The wood for this unit is a species of pine commonly found along the mid-eastern coastal areas. It consists mainly of bark together with varying quantities of culls, knots, butt-ends, and other similar wood-room refuse. Moisture content varies from 30 to 50 per cent. A representative moisture-free proximate analysis is volatile 75.42 per cent, fixed carbon 23.04 per cent, ash 1.54 per cent, and Btu per pound 9260. High-speed rotating-cylinder knife hogs assure well-sized fuel at all times. The use of this equipment adds to

steam production costs, but these are more than offset by savings in purchased fuel. Furthermore, relatively uniform size consist facilitates feeding.

Operating flexibility of this unit is illustrated by the two typical steam-flow charts shown in Fig. 7. The upper one shows a 24-hr record of almost steady steam output at approximately 100,000 lb per hr when burning low-volatile semi-bituminous coal. The lower chart is an example of wide-range flexibility when burning wood at a variable wood-room production rate. The actual load varied from 10,000 lb per hr to a maximum of 160,000 lb per hr with sudden increases or decreases of as much as 125,000 lb per hr.

A more detailed discussion of this unit's performance was presented in a paper by R. Ellwanger, Chief Engineer, of The Chesapeake Corporation of Virginia, West Point, Va., before the Virginia division of TAPPI at Richmond in September 1951, in which he said:

"The following heat balance tabulation illustrates typical performance at a rating of 130,000 lb of steam per hour:

	Per cent
Heat loss due to dry gas	5.9
Heat loss due to moisture and hydrogen in fuel	13.7
Heat loss due to carbon monoxide	0.2
Heat loss due to combustible in refuse	1.0
Heat loss due to radiation	0.5
Actual boiler efficiency by difference	78.7
Guaranteed boiler efficiency at 90,000 lb of steam per hour	75.0

"It is interesting to note that the unit is often operated at a capacity of 160,000 lb per hour for three to four hours."

Mr. Ellwanger further stated that several performance tests have indicated the total carbon loss to the stack and ashpit to be of the magnitude of 1.0 per cent, which results he attributed principally to the design of furnace and jets, as well as efficiency of the reinjection system.

Operating tests, when burning fuel oil, low-volatile or high-volatile coal, have repeatedly shown that guaranteed capacities are also easily exceeded. On one occasion an output of 160,000 lb per hour was maintained without difficulty with high-volatile (35 per cent) bituminous coal. In fact, had additional fan capacity been available, the limit might well have been raised to somewhere between 175,000 and 200,000 lb of steam per hour.

Performance was so satisfactory that there is no hesitancy in using almost any ratio of coal to wood, provided separate feeders are installed. Discharge of fuel from the wood and from the coal feeder is simultaneously conveyed to the distributor where mixing occurs. With this arrangement controls may be applied to maintain constant capacity by changing coal-feed rate to compensate for variations in available wood supply.

When burning fuel oil only, all combustion air is supplied in the immediate vicinity of the atomizing nozzles. The whirling and highly turbulent mass of burning oil vapor rapidly spins around in a narrow band, which is not much more than 12 to 14 ft wide. Immediately below and above this zone the furnace atmosphere is absolutely clear, even though excess air is held to a low level. This action clearly demonstrates that high turbulence, properly applied, will accelerate completion of the combustion process. A contributing factor is the increased time element during which individual particles of burning fuel may make one or more circuits of the furnace perimeter.

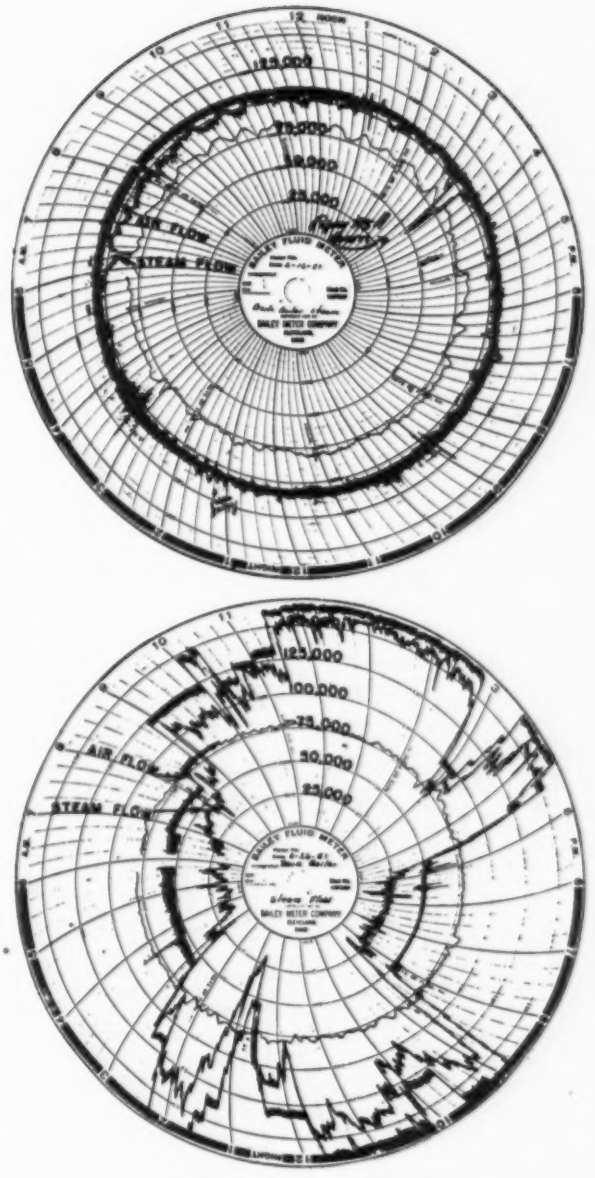


Fig. 7—Typical steam-flow charts

Notwithstanding the extremely satisfactory performance of this unit, every advantage will be taken to modify designs in the interest of still further improving operating characteristics. Some of the more recent modifications are illustrated by the unit shown in Fig. 8. Except for minor changes in arrangement of tangential nozzles and elimination of the three horizontal jet rows, the furnace is practically the same as for the unit in Fig. 6. The pendant superheater has been moved forward into the upper part of the furnace so that it now conforms more closely to those used with chemical-recovery units. A single-pass baffleless boiler has been substituted for the previously used three-pass type. This newer unit lends itself to design standardization in which capacity is a direct function of furnace width.

Regardless of the method employed for firing, the fuel size is an important factor which has considerable effect on furnace performance. It may be stated broadly that any wood refuse which can be handled by controllable feeding systems may also be used for cone burning or spreader stokers. Operating results, however, favor those installations where the oversize is hogged and size consist is maintained as constant as is reasonably possible.

For turbulent suspension burning reference has been made to a designed heat-release rate of 1,000,000 Btu per sq ft of grate per hour, without establishing any limiting factors. Selection of the actual rate to be used, however, is influenced by fuel size consist. Any considerable increase in size of the larger particles will make it necessary to carry out a greater portion of burning at grate level and thereby reduce the quantity of air used overfire. Consequently, a range of from 900,000 to 1,100,000 Btu per sq ft will prove adequate for usual variations in fuel size normally encountered. Further accumulation of a wide variety in operating experiences together with additional design changes will, no doubt, increase materially these presently established liberation rates.

It is of interest to recall that when using wet wood fuel for cone burning the design is based on an approximate grate-release rate of 500,000 Btu per square foot. Efficiency is in the order of 58 per cent. Maximum effective grate length for a single cone is 10 ft. Under these conditions capacity per foot of furnace width will be approximately 2750 lb of steam per hour. For conventional spreader installations the liberation rate is 750,000 Btu per sq ft, and an efficiency of 70 per cent provided an air heater is used, and the effective grate length 12 ft. In this case the resulting capacity is 6000 lb of steam per foot of furnace width. With turbulent suspension burning the grate length may be 16 ft or perhaps even longer. Using an efficiency of 78.7 per cent as reported by Mr. Ellwanger, and a grate release of 1,000,000 Btu per sq ft, the corresponding capacity will then be 12,000 lb of steam per foot of furnace width. This capacity-width factor together with the ability of turbulent suspension burning to quickly follow changes in steam demand and also operate over a wide load range provides the yardstick whereby the value of this new development may be appraised.

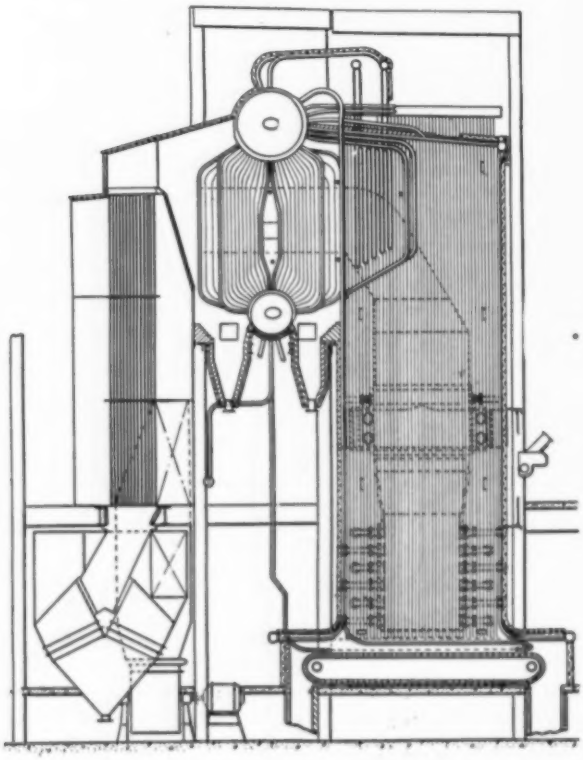
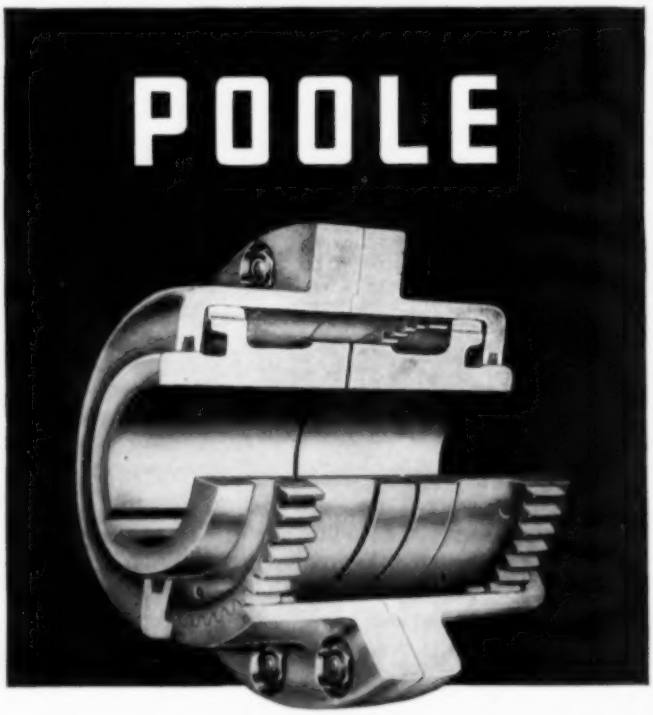


Fig. 8—Modified design of unit for turbulent suspension burning which permits extensive standardization

Large Generator to Employ Liquid Cooling

The first large generator having liquid-cooled stator conductors will be installed in the new Eastlake power station of the Cleveland Electric Illuminating Company. The rotating field windings will be cooled directly with hydrogen. Liquid cooling is said to make possible the design of units of higher capability.

This generator is part of a 208,000-kw tandem—compound G. E. unit scheduled for service late in 1955. Meanwhile, there will go into service this coming summer three 125,000-kw conventional hydrogen-cooled units, each provided with steam by a C-E controlled-circulation boiler, as will also the larger unit.



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AIEE Winter General Meeting

EIGHTY-THREE sessions and symposiums, at which were presented more than 380 papers, featured the 1953 Winter General Meeting which was held at the Hotel Statler, New York City, on January 19–23. With an attendance of more than 4500 engineers the meeting proved to be the largest held by the Institute since its founding in 1884.

In a welcoming address, **Donald A. Quarles,** president of AIEE, placed strong emphasis on increased unity within the engineering profession. He not only discussed the action already taken by the Engineers' Joint Council but also expressed the viewpoint that the unity organization should serve the common welfare, as distinguished from the welfare of one economic group as against another. He concluded his address with the following thought:

"While I do not at all imply that efforts to improve the economic status of the engineer are improper, I do hope that we can keep the objectives of the proposed national unity organization on a high professional plane, in the faith that by serving the national welfare as a prime objective, such an organization would in the long run best serve the interests of the engineering profession; and conversely, that any tendency to lower its sights and direct its efforts toward more selfish ends, would in the long run injure rather than advance the profession."

The Edison Medal was presented to **Dr. V. K. Zworykin,** RCA television and electronics pioneer, for his outstanding contribution to the concept and design of television components and systems. In a response emphasizing the impact of television on present day society Dr. Zworykin made this observation:

"The scientific application of television has been furthered particularly through the development of highly compact industrial television equipment, combining simplicity and flexibility with low cost. Television cameras weighing only a few pounds observe manipulations with explosive materials from exposed vantage points. Wherever high temperatures, close quarters, and remoteness render observation difficult, the television camera becomes an effective substitute for a human observer. In control applications it allows a single observer to watch several separated events at the same time."

Elgin B. Robertson, head of an electrical distributor firm in Dallas, Tex., was nominated for the presidency of the Institute.

Engineering Training

In a paper entitled "Management Responsibility for Development of Engineers" **Francis K. McCune** of General Electric Co. stated that any plan for the development of engineers should provide for progess along four separate but interrelated lines. These include development of (1) his technical ability, (2) organization ability, (3) professional society participation and (4) qualities to exercise leadership in society generally.

Following an extensive analysis of these areas in terms of his company's training program, Mr. McCune, in summarizing, offered the following outline of factors which should be made a part of the development of young engineers:

1. A plan for their selection.
2. A plan for specialized training and orientation and appropriate evaluation upon first coming to work.
3. A plan for advanced technical education appropriate to the aims and objectives of the company.
4. A logical and effective plan of company organization.
5. A continuous system of properly appraising the contributions of the individual engineer.
6. A strong interest in the engineer and a means for effectively guiding him along either the path of supervision and management or on the path of individual technical attainment.
7. The necessary and appropriate means for assisting the engineer to become more competent in either of the paths described.
8. A real interest in the engineer and a plan to help him with his participation in professional societies.
9. A plan to interest and stimulate the engineer not only in a field of technical or management attainment but also in the field of economic and political understanding.

Air Pollution Prevention

A paper was presented by **H. A. Bauman** of the Consolidated Edison Co., New York, entitled "Air Pollution Prevention in Electric Generating Stations." In operation of electrostatic precipitators it is of utmost importance to obtain the highest possible peak voltage on the electrodes. The ratio of the effective area of the collecting plates to the gas flow through the precipitator should be made as large as economically practicable in order to obtain high collection efficiencies. When combustible content of fly ash exceeds 10 per cent precipitator efficiency is substantially reduced. Stack design is important because much can be accomplished by better diffusion of gases into the atmosphere.

H. J. White of the Research Corporation presented a second paper on air pollution entitled "Electrostatic Precipitators for Electric Generating Stations."* This method of preventing fly ash emission has been successfully used for nearly 30 years and despite the use of lower grade coals and more stringent emission ordnances, there has been a continuing trend toward cleaner stacks and higher collection efficiency. Practical solutions now exist for most of the problems relating to the design and arrangement of precipitator equipment, including assurance of its reliable and continuous operation. However, there remain difficult problems of a functional nature arising from variations in ash characteristics, particularly its resistivity, and from stratification at the precipitator inlet.

Controllability of Central Stations

The first of two papers on this subject was presented by **P. S. Dickey** of the Bailey Meter Co., whose topic was "Controllability of High-Pressure, High-Temperature Reheat Steam Plants." The design trend toward the single boiler-turbine-generator unit has resulted in a marked reduction in the number of instruments and controllers per thousand kilowatts of plant capacity. Mr. Dickey presented a comparison of instrument costs for multiple versus single boiler units:

Plant	Date	Number of Inst. and Cont. per 1000 Kw	Cost of Inst. and Cont. per 1000 Kw
1 turbine 3 boilers	'39	19	$910
1 turbine 2 boilers	'49	165	$1222
1 turbine 1 boiler	'52	13	$748

Although use of a centralized control system results in the need for some increase in the number of remote controls and instruments required and some increase in use of alarm and protective equipment, the resulting improvement in utilization of operating manpower far outweighs any additional cost or complication of required control equipment.

The second paper in this series, "Boiler Designs Developed for Controllability," was presented by **P. R. Loughin** of The Babcock & Wilcox Co. He noted that the development and application of cyclone steam

* A more complete abstract of this paper will be published in a future issue of COMBUSTION.

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separators has greatly increased the latitude of permissible water level regulation with satisfactory steam quality and boiler circulation characteristics. Likewise, progress in devising means of steam temperature control has kept abreast of the demands imposed by higher steam conditions, increases in control range and the use of the reheat cycle.

With regard to pressure firing, one objective is to obtain higher efficiency by eliminating air infiltration and having fans pumping cold, dense air instead of hot gas. Another objective that has not yet been fully attained on large coal-fired units is to reduce initial investment by elimination of induced-draft fans, motors, dampers and controls. However, experience with seventeen pressure-fired central station boilers in successful operation has shown as improvement in controllability.

Interconnected Power Systems

C. Nichols of the Leeds & Northrup Co. presented a paper entitled "Techniques in Handling Load Regulating Problems in Interconnected Power Systems," in which he dealt with fast load fluctuations of a cyclic nature, such as fringe-load changes. One of the basic problems is to select those stations and units which will respond to sustained load changes. The magnitude and rate of these changes, together with the cost of generation on the proposed units, will determine the extent of the automatic control system for the interconnection. The trend is to distribute the generation changes in response to the sustained load changes among a large number of units in several stations in accordance with the most efficient loading schedule.

At times when fringe-load variations limit maximum power transfer on ties to neighboring areas or when the rate of change in generation in response to sustained load changes approaches the rate of change of fringe-load variations, investigation should be made of the possibility of controlling generation automatically in response to fringe changes. If it is found necessary to control in this manner, it is highly desirable from an operating standpoint that the percentage of fringe action assigned to the regulating stations and units be adjustable independently of the percentage of the sustained control action assigned to these stations and units.

"Effect of Swinging Loads on Steam Plant Economy" was the subject of a paper by **W. D. Wilder** and **H. J. Thielke** of the U. S. Department of Interior, who presented a preliminary

progress report on a series of tests at the Huntley Station of Niagara Mohawk Power Corporation. These tests represented an attempt to determine the magnitude of additional costs due to swinging loads and were run under normal operating conditions. For any given load level, two tests were run, one under steady load and a second under swinging load conditions. Three turbine-generators were used, one operating on a header system at 425 psig, 750 F, and the other two with single boilers, one delivering steam to the throttle at 1250 psig, 900 F, and the other at 1250 psig, 950 F. The authors concluded, on the basis of test results, that only minor increases in steam electric production costs are due to carrying swinging loads. These increases are of such small magnitude that they might well be caused by inherent inaccuracies of the measuring devices used.

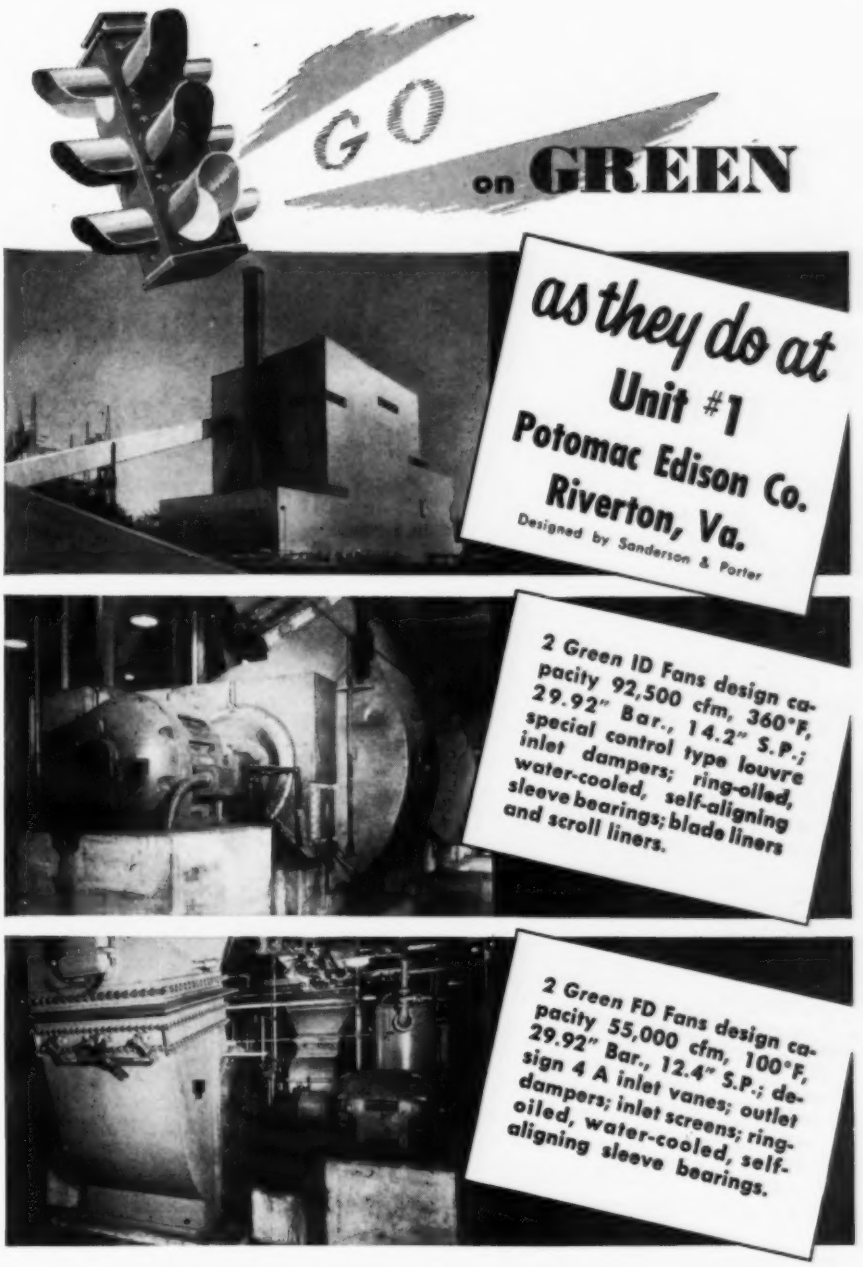
In a paper entitled "Principles of Load Allocation Among Generating Units," **E. E. George** of Ebasco Services, Inc., pointed out that there is not much information available on the overall incremental efficiency of boiler, turbine-generator and auxiliaries at loads between nominal name plate rating and maximum capability. Also, there is no generally accepted definition of maximum capability, and data are lacking as to the effect on efficiency of either large or small output variations about a given average output as compared with continuous operation at the same output.

In summary Mr. George stated that it is necessary to reconcile many electrical and mechanical considerations in scheduling system generation. The plant supervisor should be responsible for determining availability, minimum and maximum loads, permissible rates of output change, efficiencies, fuel costs and other operating and maintenance problems. Whether to use a unit and at what load is the responsibility of the load dispatcher who is in a position to consider availabilities and costs of other units, total system load, interconnection schedules and various electrical limitations.

Nuclear Power Plants

In a paper which outlined some of the possibilities of the development of nuclear power reactors, **John Menke** of Nuclear Development Associates expressed a rather optimistic viewpoint toward the commercial feasibility of power generated from nuclear sources. Deposits of uranium, the basic fuel for the breeding process, are widely distributed geographically, the largest and most important being in

(*Continued on page 65*)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2 Green FD Fans design capacity 55,000 cfm, 100°F, 29.92" Bar., 12.4" S.P.; design 4 A inlet vanes; outlet dampers; inlet screens; ring-oiled, water-cooled, self-aligning sleeve bearings.

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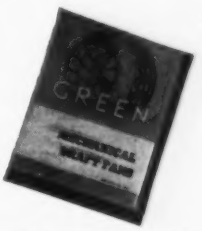

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HALL INDUSTRIAL WATER REPORT

Hall Laboratories, Inc.—A Subsidiary of Hagan Corporation, Pittsburgh, Pa.

Volume 1 | FEBRUARY 1953 | Number 1

New Water Manual Published by ASTM

Of interest to everyone concerned with industrial water is ASTM's "Manual of Industrial Water," a January 1953 release, prepared by Committee D-19. Manual discusses uses of industrial water, difficulties caused by industrial water, compositions of waters and deposits, treatment, sampling, analysis of water, identification of water-formed deposits.

Research by Hatch Gives New Basic Facts on Threshold Treatment for Corrosion Control

Research papers by Dr. G. B. Hatch of Calgon, Inc., titled "Protective Film Formation with Phosphate Glasses" and "Inhibition of Galvanic Attack of Steel with Phosphate Glasses" provide a better scientific understanding of the mechanism of film formation with Calgon.

Data prove Calgon stops corrosion by virtually eliminating flow of current between anode and cathode in corrosion cells.

Research shows Calgon is a cathodic inhibitor. All cathodic inhibitors are "safe" inhibitors, because they do not increase tendency toward pitting.

Data reveal that protective film is formed by electrodeposition process, and that Threshold Treatment for corrosion is quite different from Threshold Treatment for scale prevention.

Write if you want a free copy of these fundamental papers.

Industrial Water Statistics

According to U. S. Dept. of Commerce statistics, use of industrial water for process has been estimated at 80 billion gal per day during 1950. This is 8 times the quantity required in 1900, although population increase in same 50 years was only 2-fold.

Manufacture of steel, production of electric power require 50 billion gallons of the 80 billion per day. Industrial use of water is estimated to increase 170 per cent from 1950 to 1975, according to Materials Policy Commission.

Pilot Plant Designed for Steel Company Results in Minimum Cost for Waste Disposal

A Pennsylvania steel company had to dispose of wash waters evolved in the manufacture of producer gas.

This wash water contained objectionable quantities of phenol, sulfide, and cyanide.

Preliminary study showed that either chemical treatment, or closing up wash water system could do the job. A Hall Labs staff engineer recommended use of a pilot plant to determine chemical treatment costs. He specified equipment for pilot unit, and provided detailed instructions for operation. Pilot plant showed that all hydrogen sulfide and cyanide and about 90% of phenol could be removed.

But cost analysis of chemical treatment revealed it was 2 or 3 times as costly as closing up system. On this basis, decision was to install a recirculating system for the producer gas wash water.

Major problem in closed system was build-up of suspended solids. Methods of controlling this were studied by the Hall staff, and recommendations made to steel company.

State antipollution requirements were satisfied, and another step taken toward clean natural streams with the minimum cost to industry.

Field Reports on Industrial Water Treatment

Herman Reda, Service Engineer in our Detroit Office, made the following report on a food processing plant in his area:

"*Turbines have now operated continuously for 3½ years. Prior to use of Hall System, plant had to clean units every 6 months.*"

A report on boiler water control comes from Bill Pfeiffer of the St. Louis Office. Report concerns a paper company:

"*Client is pleased with silica treatment. After silica had been fed for about 3 months, boilers were opened for inspection, found to be much cleaner than client ever saw before. Heavy sludge usually found in top rear drum and mud drum was almost gone. Silica is also helping out at the filters, and filtered water contains no suspended matter. Client cleaned filters with Buromin—pleased with results.*"

"Calgon" and "Buromin" are names of phosphate glasses developed by Hall Laboratories for industrial water treatment and marketed, respectively, by its associates, Calgon, Inc., and the Buromin Company who have registered the names in the U.S. Patent Office as trademarks. "Hall System" is similarly registered as a service mark by Hall Laboratories.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information, write, wire or call Hall Laboratories, Inc., P.O. Box 1346, Pittsburgh 30, Pennsylvania.

Water is your industry's most important raw material. Don't waste it.

HALL LABORATORIES, INC.—CONSULTANTS ON PROCUREMENT, TREATMENT, USAGE AND DISPOSAL OF INDUSTRIAL WATER

(*Continued from page 63*)

the Belgian Congo. Next largest deposits are found in the Colorado plateau of the United States, while Canada ranks third as a source of this raw material. A second possible fuel for nuclear energy power plants is thorium, of which there are large deposits in India, Brazil and the state of Idaho.

The breeding process is attractive from a commercial viewpoint because it affords the possibility of making available plutonium for re-sale. Plutonium has value as (*a*) an initial charge in new power plants, (*b*) as a fuel for atomic engines in naval ships and military airplanes and (*c*) for nuclear weapons.

The economics of the nuclear reactor must be based on consideration of operating costs of a non-fuel type, very large capital investments, and negligible fuel costs. These must be compared to the conventional steam plant with operating costs well established through years of experience, moderate capital investment and substantial fuel costs.

Mr. Menke was strongly of the opinion that free enterprise could make a substantial contribution to nuclear energy plants by reason of its continued preoccupation with cost factors. He pointed out that many technical difficulties would have to be overcome, including the finding of methods of taking care of heat releases in the reactor core on the order of one kilowatt per cubic centimeter. However, he felt that these and other engineering problems could be solved by private capital, thus providing a military asset in peacetime without cost to the government and one that readily could be converted to military use in time of war.

M. A. Schultz of Westinghouse Electric Corp., in a paper entitled "Nuclear Power Plant Control Considerations," pointed out that in considering the output of a nuclear reactor there is no such thing as "zero power." Even in a new reactor which has been shut down as much as possible, an inherent source of neutrons exists which causes a certain amount of nuclear fission to occur and produces minute amounts of power. Because of the existence of secondary radiations emitted from fission products, serious amounts of power from these sources may be given off even though the reactor has been turned off to the best of the ability of the operator. From a control standpoint this means that auxiliary devices may be necessary to dump this spare power into a useless load.

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Advances in Synthetic Fuels Technology

Technical advances in producing synthetic liquid fuels from coal and oil shale for the eighth full year of Bureau of Mines activity under the Synthetic Liquid Fuels Act of 1944 are covered in a progress report just submitted to the Congress for the year 1952. Highlights of the report are:

1. Advances in oil-shale technology, featuring the completion of a 200-ton-a-day oil-shale retort, incorporating the Bureau-developed gas-combustion process.

2. Successful operation of a pilot plant for retorting oil-shale fines continuously at high temperatures to produce high-test gasoline and chemicals.

3. Experiments in gasification—an important step in producing oil from coal—whereby pulverized coal is gasified successfully with oxygen and steam at pressures up to 450 psi with greatly increased throughput.

4. Advancing underground gasification of coal to the point where it was shown that gas suitable for producing synthetic fuels, pipe line gas, or chemicals can be made.

5. Progress in coal hydrogenation in which the Bureau developed the first American vapor-phase catalyst and produced liquid fuels on a demonstration scale from Pittsburgh seam coal and North Dakota lignite.

6. Gas-synthesis research, which produced a durable Fischer-Tropsch catalyst and an economical process for removing carbon dioxide from synthesis gas.

The extensive interest of industry in the Bureau's synthetic liquid fuels program is demonstrated by the number of companies that have joined the Bureau in cooperative projects. Of 134 such agreements in effect during the year, 92 were between the Bureau and private industry, including engineering, construction and equipment concerns and oil, chemical and coal companies. The remainder were between the Bureau and educational institutions, individuals and other Government agencies. Outstanding among the industrial cooperative agreements are those with the Alabama Power Co. for underground gasification of coal, with Babcock & Wilcox Co. on development of pulverized coal gasification, and with Standard Oil Co. of California, Koppers Co., Inc. and Blaw-Knox Construction Co., which provide resident engineers at the Rifle, Colo., oil-shale project.

Oil from Shale

At the Oil-Shale Demonstration Plant, Rifle, Colo., experimental data on the gas-combustion process were obtained in a ten-day retorting run on shale of about the grade that would be used in a commercial plant. Retorting facilities are being expanded by construction of a 50-ton-a-day unit. Plans were made to begin operating the new 200-ton-a-day gas-combustion retort early in 1953. The gas-combustion process, which dispenses with external heating and cooling equipment and reduces water consumption, is particularly important because the country's large oil-shale deposits are in a semi-arid region.

At the Bureau's Laramie, Wyo., station, successful operation is noted of a new pilot plant in which oil shale fines are retorted at high temperatures. Flexibility in temperature and time variation permits control over the quality and type of products obtained by the entrained-solids method. High yields of regular- and premium-grade motor fuels, important aromatic chemicals, and chemical raw materials can be produced.

Oil from Coal

During the year the Bureau concentrated on pressure gasification as a means of reducing costs in the gas-synthesis and coal-hydrogenation processes. Thirty-two runs were made on the pressure gasifier at the Morgantown, W. Va., station. Over 1300 tons of coal per hour was fed into a reactor and gasified under pressures up to 450 psi. Reactor capacity at this pressure was about 800 lb of coal per cubic foot compared with only 10 to 20 lb of coal at atmospheric pressure.

Other work at Morgantown included 34 runs on the atmospheric-pressure gasifier, tests on preheating of the coal-feed stream, and installation of a new oxygen-producing plant.

Underground Gasification of Coal

The Bureau of Mines, cooperating with the Alabama Power Co., installed and operated three-unit underground gasification systems at Gorgas, Ala., during 1952. Using an electrolinking-carbonization process originated by the Sinclair Coal Co. and the Missouri School of Mines to open the initial passage, there were produced 1.1 million cubic feet of 83-Btu gas per day from the first unit, and an average of 2.2 million cubic feet of 95-Btu gas per day

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from the second and third units combined. Combustible gas was produced steadily during these operations for periods up to three months.

Operation of the third unit at Gorgas with alternate blasts of air and steam indicated the possibility of producing a 300-Btu synthesis-type gas. Gasification with oxygen was attempted for the first time late in the year. Oxygen was pumped into the third unit to produce a synthesis-type gas and, although oxygen usage was high, it is believed it can be reduced in further work.

Gas-Synthesis

With the indirect or gas-synthesis method of producing oil from coal, the coal is gasified with oxygen and steam. The purified synthesis gas, consisting of carbon monoxide and hydrogen, is passed over a catalyst and converted into liquid fuels. The process yields gasoline, jet fuel, diesel oil and heavier oils.

Technologists at the Bureau's Bruceton, Pa., laboratory have devised a new technique for activating steel shot and iron turnings which produced a sturdy, long-lived Fischer-Tropsch catalyst. One of these catalysts was used for six months. Pilot plant tests at Bruceton indicated that scrubbing impure synthesis gas under pressure with hot, concentrated potassium carbonate is more economical than conventional methods for removing carbon dioxide. Experiments made with nitrided iron catalysts showed that this modified gas-synthesis process yields large quantities of higher alcohols.

The Gas-Synthesis Demonstration Plant at Louisiana, Mo., made four exploratory runs during 1952. During one run 85 per cent conversion of the gas was achieved without undue catalyst deterioration.

Coal Hydrogenation

Coal hydrogenation is a two-phase process. In the liquid phase, pulverized coal mixed with oil from the process is reacted directly with hydrogen in the presence of a suitable catalyst and under pressure. The product obtained—a heavy oil—is run through a vapor phase in which it is "converted" to gasoline and other products.

In 1952 the Bureau's hydrogenation demonstration plant at Louisiana, Mo., completed two extended liquid-phase operations and one vapor-phase run. The heavy oil obtained from northern Wyoming and Illinois coals in liquid-phase runs was converted in the vapor phase to 435,000 gal of 76- to 77-octane (motor method) gasoline and 27,000 gal of oil. Also, 2,250 tons of Pittsburgh seam coal was processed in a liquid-phase run to yield 240,000 gal of vapor-phase charging stock and 116,000 gal of solids-free heavy oil. Late in the year, hydrogenation of 3000 tons of North Dakota lignite was begun.

At Bruceton, Pa., work began during the year on a new single-phase hydrogenation process. Virtually complete hydrogenation of bituminous coal was achieved with a short reaction time in batch laboratory tests, and continuous plant tests are under way.

Personals

Dr. R. C. Ulmer, well known in the power field as a feedwater specialist and for the last seven years technical director of E. F. Drew & Co., has joined the Engineering Department of Combustion Engineering-Superheater, Inc., New York, where he will be engaged in development work.

A graduate of Ohio State University, from which he later acquired his doctorate, Dr. Ulmer spent some years as a chemist in the Research Department of The Detroit Edison Company where he was associated with many power plant operating problems. He has written many technical papers and articles and holds membership in The American Society of Mechanical Engineers, The American Chemical Society, The American Society for Testing Materials, The American Water Works Association and The National Association of Power Engineers.

William G. Christy, until recently director of New York City's Bureau of Smoke Control, has opened a consulting engineering office at 34 Park Row, New York, and will specialize in problems of air pollution control, combustion, refuse burning and smoke control.

Lyle B. Schueler, long well known as a utility engineer and more recently associated with Diamond Power Specialty Corp., has been elected vice president in charge of that company's sales. He is located at Lancaster, Ohio.

Arthur H. Kuljian, chief mechanical engineer of The Kuljian Corp., engineers and constructors, Philadelphia, has been elected vice president of that company. He has long been identified with the design of steam power plants.

Edward F. Brill has been appointed chief engineer of the Allis-Chalmers Atomic Power Section. He is a graduate mechanical engineer of the University of Wisconsin and a bachelor of law degree from Marquette University.

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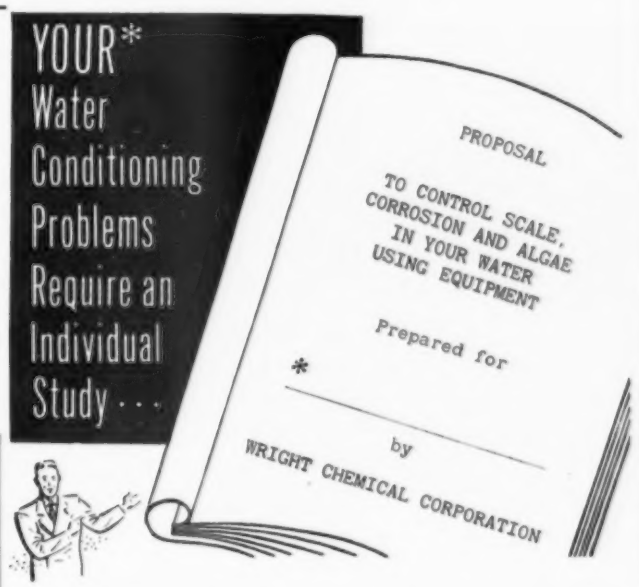

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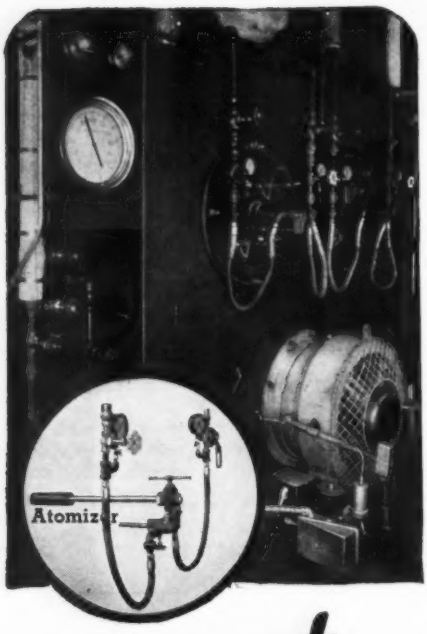

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Enco Atomizers are used with various types and makes of pulverized-coal and gas-burner units to provide a dual fuel unit for cold starting, or for full-load operation when coal or gas is not available, or use when oil is the more economical fuel.

We have made many installations during the past 25 years and are ready to cooperate with those looking for better operation and assurance against loss of steam output.

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NEW CATALOGS AND BULLETINS

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Regulator Selection

A useful 36-page illustrated "Step Selection Chart" has been issued by the Foster Engineering Company to simplify the selection of proper types and sizes of pressure and temperature regulators and pump governors. One interesting table provides valve capacities in pounds of steam per hour for numerous initial and final steam conditions up to 1500 psig and valve sizes from $^1/_2$ in. to 12 in.

Boiler Control

Bulletin 1007 prepared by the Copes-Vulcan Division of Continental Foundry & Machine Co. illustrates and describes the new Copes-Vulcan boiler control with instrumentation by Taylor Instrument Co. It includes descriptions of combustion, feedwater, boiler steam temperature and soot blower controls. Standard or miniature instruments and conventional, console or graphic panels are also shown in the 10-page booklet.

pH and Conductivity Recorders

Brown Instruments Division of Minneapolis-Honeywell Regulator Co. has issued Catalog 1550, a 24-page publication which includes information on recorders, controllers, amplifiers and electrodes useful for electro-chemical measurement. One section of the bulletin takes up underlying theories of such measurement.

Reciprocating Pumps

Installation, operation and maintenance of reciprocating pumps is covered in a 20-page service manual prepared by the Warren Steam Pump Co. Steam consumption curves are provided for horizontal duplex-piston pumps, as well as instructions for valve setting.

Insulation Specifications

Johns-Manville has issued a 52-page illustrated brochure entitled "J-M Insulation Specifications for Oil Refineries and Chemical Process Plants." It is designed as a quick reference for those writing thermal insulation specifications. These are divided into four main sections: (1) insulations for temperatures above 100 F, (2) insulations for temperatures below 100 F, (3) tank insulations and (4) oil heater insulations.

Ion Exchange Processes

An extremely informative 28-page bulletin, No. 3803, has been prepared by The Permutit Company to help explain the functions that ion exchangers are playing in the demineralization of water. Following an introductory explanation of basic principles, the bulletin contains schematic diagrams and brief descriptions of equipment for demineralization and silica removal, including the following processes: two-step with or without degasifier, mixed-bed, three-step and four-step with degasifier, and cation exchanger with mixed bed and degasifier.

Coal Distributors

Stock Equipment Company has issued Bulletin No. 73 which explains the theory of the Conical nonsegregating coal distributor. Descriptive material and illustrations show how this device prevents the coal segregation that results from the use of a flat chute in distributing coal to a stoker. Accessories that can be used with the distributor are also shown in photographs.

Oil Burner

Bulletin 25 issued by the National Airoil Burner Co., Inc., describes a new dual-stage burner combining steam and mechanical atomization. A detailed description of the burner and its uses, along with specifications, is included in the 4-page bulletin.

Deaerating Heater

Graver Water Conditioning Co. has released a four page bulletin showing a compact package-type deaerating heater which is completely equipped with all accessories. Distinctive features are described, and tabulations of sizes and capacities of vertical and horizontal heaters are provided.

Electrode Rapping System

A 6-page bulletin with illustrated information on the recently developed magnetic impulse, continuous electrode rapping system for electrostatic precipitators has been announced by Research Corporation. The M. I. system, as it is known, is of the continuous, self-monitoring electrode-cleaning type

that improves overall precipitator efficiency and reduces operating costs. Operation of this system is explained with circuit diagrams and photographs of major components.

Purifiers

An 8-page folder published by the V. D. Anderson Co. under the title, "End Dirt and Moisture Problems the Hi-eF way" describes the many uses of purifiers (mechanical separators) in steam generation and distribution systems and in the process industries. Cutaway views showing the installation of purifiers in 14 different applications are accompanied by a brief description highlighting their purposes in each case.

Control Panels

The engineering and economical planning of modern combustion and process control panels is discussed in a new 8-page bulletin, No. 170, issued by the Bailey Meter Co. Numerous panel designs are illustrated along with up-to-date methods of tubing and wiring. There is also a section on panel accessories suitable for central-station application.

Vertical Pumps

Construction features of Allis-Chalmers small vertical pumps for sidewall or submerged mounting are described in a new 8-page bulletin, No. 52B6975A, released by the company. Helpful curves and tables to determine motor frame, horsepower, speed and current characteristics for the various units are included in the bulletin.

Hook-On Instruments

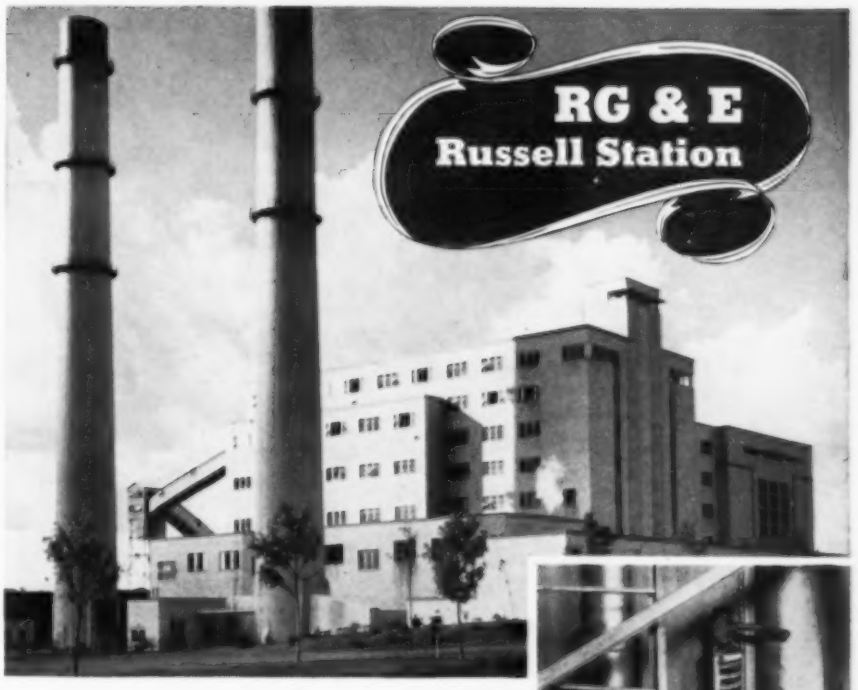
An 8-page booklet describing General Electric's complete line of hook-on instruments has been announced as available. Designated GEC-901, the two-color bulletin contains applications, operation and basic features of voltammeters, wattmeters and power factor meters of this type.

Air Compressors

Oil-free air compressors are discussed in Bulletin A-92 released by Joy Manufacturing Co. Specifications shown include compressors ranging in size from 172 to 8800 cfm, 25 to 600 hp.

Steam Traps

Armstrong Machine Works has issued Bulletin 215 which covers the purpose, operation, physical data, capacities installation and prices of their piston-operated compound traps. Instructions for installation and operation are also included.



Safety Valve Report:

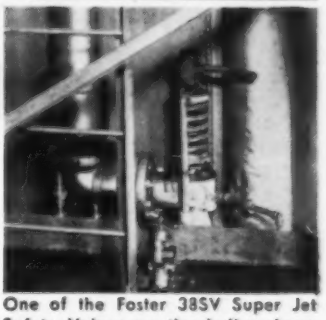
- **"2 YEARS IN SERVICE...**
- **NO MAINTENANCE...**
  STILL TIGHT!"

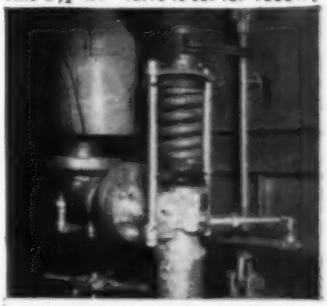
That's the report from Rochester Gas & Electric Co. on the Foster Super Jet Safety Valves on the #2 unit of their new Russell Station.

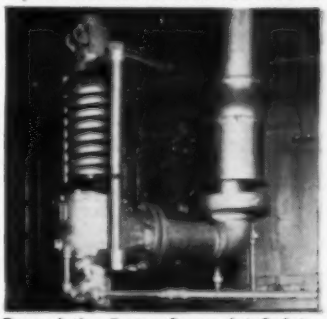
Other points they like about these valves are their greater capacity, so that fewer valves are necessary, and their accessibility for inspection and service.

Foster Super Jet Safety Valves give better protection two ways: absolute protection against overpressure, and greater protection against costly outages caused by service failures.

For full information on Foster Super Jet Safety Valves, ask for Bulletin 80-SV.


One of the Foster 38SV Super Jet Safety Valves on the boiler drum. This 2½"x4" valve is set for 1680#.


This 2½"x4" Foster Super Jet on the superheater header is set for 1600#.


One of the Foster Super Jet Safety Valves on the reheater inlet header. This 4"x6" valve is set for 530#.

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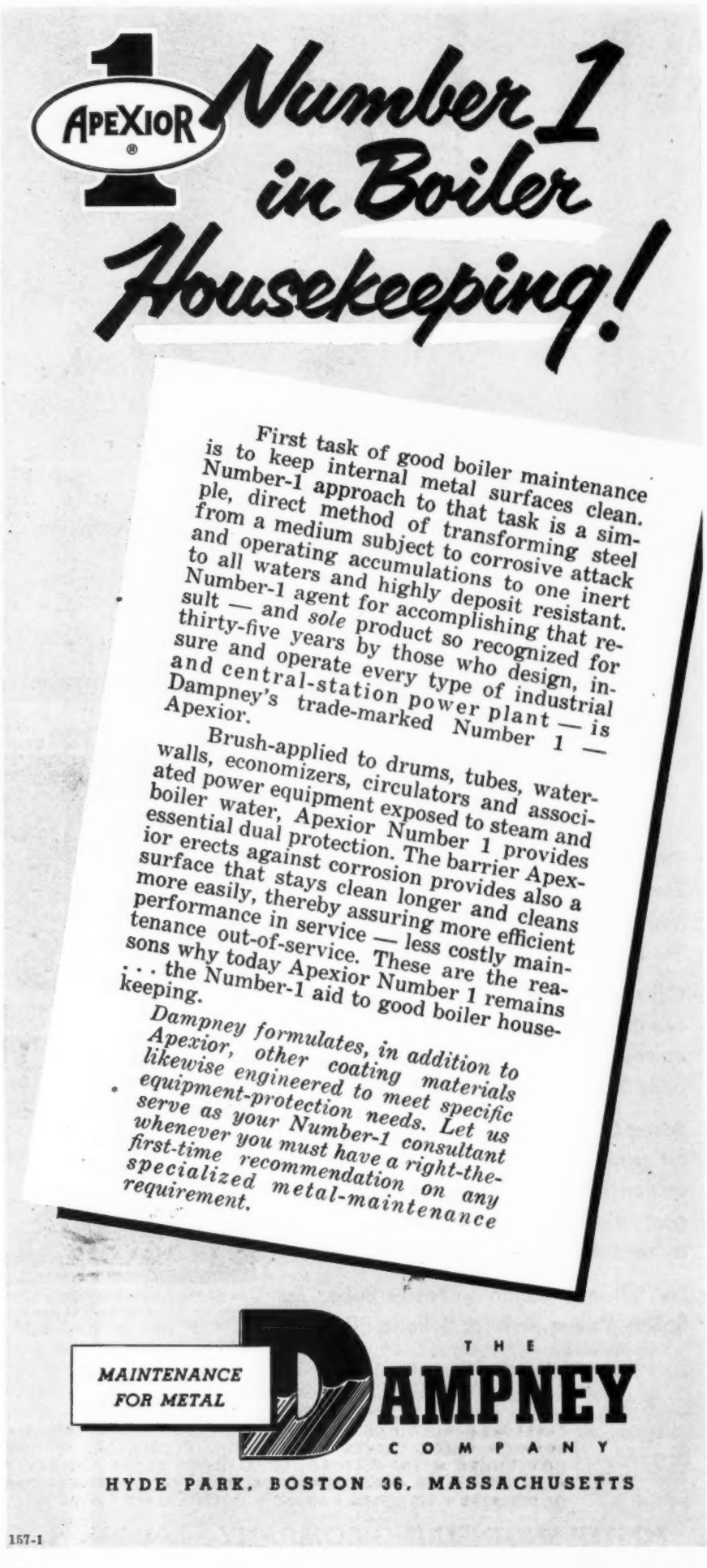
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Search for Sources of Rare Electronic Element

A search for additional sources of the costly metal germanium for use in radar and other electronic equipment of the Armed Forces has been launched by the United States Bureau of Mines in ash pits and smoke stacks of large industrial consumers of coal.

This rare element, now produced in the United States in small amounts as a by-product of zinc refining and selling at around $350 per lb, also appears in minute quantities in many American coals; but at present it is said to be uneconomical to recover it directly from the coal. The best method is to extract it from the ash resulting from the burning of the coal.

The search is being concentrated on certain of those central station power plants that burn a total of more than 100 million tons of coal yearly.

Germanium is recoverable from coal ash as a compound that can be converted to metal—its most useful form—by carefully controlled processes. Its most popular uses today are in electronic diodes for rectifying high-frequency circuits and in the recently developed transistors, only a fraction the size of the smallest electron tube, which they ultimately may largely replace because they are lighter, last longer, use less power and are more compact.

Corrosion Engineers' Meeting in Chicago

Titles of seven papers in a chemical industry symposium scheduled to be delivered at the National Association of Corrosion Engineers' Conference in Chicago, March 16–20, 1953, have been announced as follows:

"Use of All-Plastic Equipment and Piping in Technical Corrosion Protection" by J. L. Huscher, American Agile Corp.

"Corrosion by Acids at High Temperatures" by R. F. Miller, R. S. Treseder and A. Wachter, Shell Development Company.

"Metallurgy of Corrosion" by F. Prange, Phillips Petroleum Co.

"Statistical Analysis of Corrosion Data by O. D. Ellis, Armco Steel Corp.

"Corrosion Study in a Salt Plant" by H. B. Rickert, Michigan Chemical Co. and H. O. Teeple, International Nickel Co.

"The Behavior of Titanium in Sulfuric and Hydrochloric Acids" by G. C. Kiefer, Allegheny Ludlum Steel Corp.

The meeting will be held at the Sherman Hotel.

Business Notes

The **C. O. Bartlett & Snow Co.**, Cleveland, has appointed John R. Hersey assistant sales manager. He will, however, continue to head the company's coal-handling department. Also, Harry C. Orr has been named manager of the company's standard products, repair parts sales and service department.

Cyrus Wm. Rice & Co., water consultants of Pittsburgh, has appointed A. B. Young as its sales representative in Indiana with offices at 1517 E. 81st St., Indianapolis. It has also named the Nevans Co. of Houston, Tex., to represent Rice services in Texas and Louisiana.

Westinghouse Electric Corp. has named C. B. Campbell and J. R. Carlson, respectively, to the positions of consulting engineer and manager of engineering for its Steam Division at Philadelphia.

Edward Valves, Inc., has opened a new two-story engineering building at its works in East Chicago, Ind. Built almost entirely of stainless steel and glass the new building is located adjacent to the company's laboratory and research building in order to permit easy contact between the engineers and the laboratory technicians.

The **Copes-Vulcan Division of Continental Foundry & Machine Co.**, Erie, Pa., announces the following new representatives: Barnes Engineering Co., Indianapolis, Ind.; Pacific Steam Control Co., Seattle, Wash.; Cochrane Engineering Corp., 309 W. Jackson Blvd., Chicago; Gil Moore & Co., 515 Harrison St., San Francisco and 714 W. Olympic Blvd., Los Angeles; and W. E. Veenschoten, 27 Gaywood Circle, Birmingham, Ala.

Chain Belt Company of Milwaukee has announced several executive changes. These include appointment of Luther H. Bosnian to vice president in charge of manufacturing facilities; Lyman E. Newton as controller; D. F. Tincknell, assistant treasurer. Also, Bernhard E. Schneider has been appointed to the newly created post of assistant chief engineer and four new sales engineers as follows: James W. Mueller, Chicago; Dabney P. Murrill, Atlanta; Robert B. Hill, Portland, Ore.; and William C. Beals, Buffalo.

Pennsylvania Crusher Company, Philadelphia, has appointed the Mine and Smelter Supply Company of Denver and El Paso to represent it in New Mexico, Arizona, Western Texas, Colorado, Western Kansas, Nebraska, So. Dakota, Eastern Wyoming and Montana.

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